BSR

Energy Management Handbook

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About The Handbook

China has an ambitious goal of cutting energy consumption per GDP by 20 percent of 2005 levels by 2015. To reach this goal, the government created the Comprehensive Scheme on Energy Saving and Emission Reduction in August 2011. The scheme is directed at large enterprises in key industries such as power generation and construction materials. Small and medium-sized enterprises, however, account for half of China's total annual energy consumption and are about 30 to 60 percent less energy-efficient than larger companies. Improving energy management of SME scan significantly help China achieve its energy conservation and emissions reduction goals.

This energy management handbook was created by BSR, a leader in sustainability management, after a series of studies on manufacturing SMEs. The studies examined the challenges faced by these companies, and explored cost-effective energy-saving methods. This booklet teaches SMEs how to establish energy management systems, explains the concepts and procedures of an energy audit, and introduces methods of energy efficiency diagnostics as well as energy efficiency technologies and best practices. We also make practical and easy to operate recommendations to SMEs from both management and technical perspectives.

The handbook was written by Fengyuan Wang of BSR Hong Kong and Andy Chen of BSR Guangzhou. The authors would like to thank Starbucks Coffee Company and its China-based suppliers for their contribution in the research, and the British Foreign & Commonwealth Office for its funding support.

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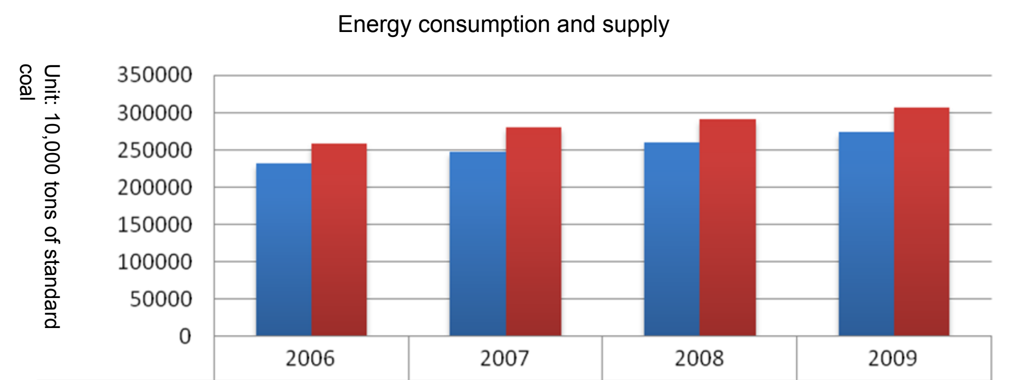
Energy Management System

1. Overview

China's huge population and rapid pace of economic growth make its energy needs particularly challenging. After two decades of annual growth averaging eight percent, it is now the world's second largest energy consumer after the United States, according to the International Energy Agency (IEA). China's National Bureau of Statistics reports consumption of coal in China rose 18.6 percent to 3.06 billion tons in 2009, outpacing supply, which rose 18 percent to 2.74 billion tons from its 2006 equivalent. (See Table *1-1 Energy consumption and supply (2006-2009) below).* As a result, the government is facing a series of challenges to expand its energy supply while increasing efficiency.



	2006	2007	2008	2009
Gross energy production	232167	247279	260552	274618
Total energy consumption	258676	280508	291448	306647

Table 1-1: Energy production vs. energy consumption (2006-2009)

The bulk of the demand comes from the industrial sector, which is often hampered by shortages as rising consumption puts pressure on domestic energy reserves. In 2011, China's major industrial provinces, Guangdong, Guangxi, Guizhou, Yunnan and Hainan, suffered from the worst power shortages since 2006. In May 2011, power regulators were forced to impose "off-peak " periods in the Pearl River Delta industrial area of Guangdong province, affecting industrial towns located in the area, namely Dongguan, Shenzhen and Foshan, in an attempt to reduce power consumption.

To meet year-end targets, 60 percent of small factories in Dongguan for instance, only received electricity three days a week, while companies in Baoan and Shenzhen had six days of electricity supply, as opposed to seven full days. Similarly, factories in 21 towns in Dongguan, including Shijie, Tanxia and Dalang only operate four days a week. These severe shortages combined with the rising value of the Yuan have raised costs for local businesses and depleted their profit margins.

China is at a highly energy-intensive stage of growth, consuming nearly 10 percent of the world's energy resources. But government intervention through the introduction of energy saving schemes presents opportunities to enhance efficiency in the industrial sector. Companies, the majority of which are SMEs, will benefit from implementing such schemes to help them reduce power usage, increase energy efficiency and reduce costs.

The following chapters explain the benefits of implementing energy management systems and offers best practice advice to help SMEs use energy more efficiently.

ENERGY MANAGEMENT SYSTEM STANDARDS: ISO50001 AND GB/T23331-2009
China's Standard Certification Center (CSC) began research into improving energy management systems and upgrading national standards in 2002. In 2009, the government implemented its newly developed research GB/T 23331-2009, "Requirements for Energy Management Systems." Since then, China has made regular updates to its systems to match national standards with those of the International Organization for Standardization (ISO), which published its latest international energy management standards, the ISO 50001, in June 2011.

Organizations across the world face energy-related challenges, including those related to energy supply, reliability and climate change matters. The ISO 50001 is a framework that helps companies manage their energy systems and plan better to save energy and to reduce pollution as well as costs. ISO estimates these standards can reduce global energy consumption by 60 percent.
The ISO 50001 provides the following benefits:

» Resolves energy efficiency problems
» Improves energy usage of energy-consuming assets
» Estimates environmental impact of greenhouse gases;
» Improves energy management and communication;
» Provides best practices for energy efficiency;
» Prioritizes new energy-saving technology;
» Improves energy efficiency of supply chains; and
» Details greenhouse gas reduction plans

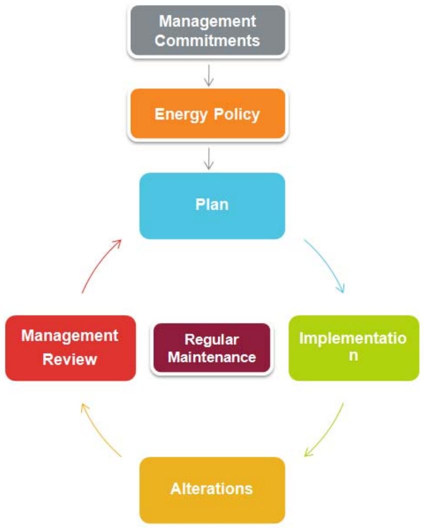


Figure 1-2: Energy Management Model

Both ISO50001 and GB/T23331-2009 are based on the same model (See Fig.1-2 Energy management model), which applies the "Plan, Do, Check and Action" cycle (PDCA). This handbook provides China-based companies, particularly SMEs, with an overview of ISO 50001 as it relates to the Chinese GB/T23331-200 standard.

2. Establishing an Energy Management System

2.1 MANAGEMENT COMMITMENT

Both international and Chinese energy management standards require the support of senior managers to commit to facilitating energy efficiency throughout their organizations. These include commitments to establish, implement, maintain and improve energy management systems on a regular basis.

Specifically, managers must commit in writing to:

» Integrate energy policies and regulations into company operations;
» Incorporate energy targets into overall business strategies;
» Provide staff with energy management training;

» Conduct management reviews of energy management processes; and

» Keep energy-related equipment well maintained.

Energy Saving Commitments

» Establish a system to collect, analyze, and report data related energy consumption, and ensure correctness and integrity of that data;
» Designate personnel with expertise and technical experience, or above, to be in charge of energy management, and file this personnel in government agencies in charge of energy saving;
» Enhance measuring instrument management and equip and use qualified measuring instruments according to relevant regulations;
» Establish a responsibility system and award organizations and individuals with good performance in energy-saving activities;
» Make and implement energy-saving plans and technical measures;
» Comply with national energy limitation standards and make corporate standards that are stricter than national standards;
» Use energy efficiency markings on products according to relevant regulations;
» Conduct energy-saving education and training regularly;
» Never produce, import, or sell any products or equipment (or use equipment) that are clearly specified as "to be eliminated" by government agencies or those which do not conform with energy efficiency standards;
» Never provide free energy to employees or implement any "package fee" system for energy use.

These commitments should be printed and posted in public areas in the factory to promote energy management.

A good energy manager should display the following competences:

» A senior/middle class manager who can report to the top management directly;

» Be familiar with main production processes;

» Have a certain understanding of production equipment, electrical, boiler, air-conditioning, lighting, and auxiliary systems;

» Have a certain degree of financial knowledge and energy management; and

» Strong management ability and is able to implement improvement plans independently.

2.2 ENERGY POLICY (OPTIONAL)

National and international energy management standards encourage companies to create energy policies specific to their company operations. But implementation of these policies is up to the discretion of managers and companies.

Good energy policies:

» Are integrated with the company's business activities, products and services;

» Reduce energy consumption, increase efficiency and guarantee regular system maintenance;

» Comply with applicable laws and regulations;

» Provide a framework for making and evaluating energy targets and indicators;

» Offer employees training materials so that they can understand and implement energy policies; and

» Are readily available to all relevant parties within the organization.

2.3 ENERGY MANAGER

Senior executives must assign an independent specialist to oversee energy management within the company, with the exception of SMEs, whose directors

EXAMPLE- **Energy management organization chart**

Leader:
Vice General Manager

Members:
Production Supervisor
Equipment Engineer
Financial Supervisor

are allowed to designate an internal energy manager from their middle-level management staff. In this case, the standards recommend appointing a supervisor or higher-level executive from the production, maintenance or engineering divisions.

The energy manager is required to:

» Establish, implement, maintain, and improve energy management systems in accordance to the national and international standards;

» Provide regular updates to top management on all energy management systems;

» Submit proposals for improvements; and

» Liaise with external organizations on energy management issues.

2.4 PLANNING

The energy manager is responsible for developing an action plan in line with national and international standards, the first step in the "Plan, Do, Check and Action" cycle.

Any plan must:

» Identify key energy performance indicators;

» Adhere to rules, regulations and other requirements that affect management systems;

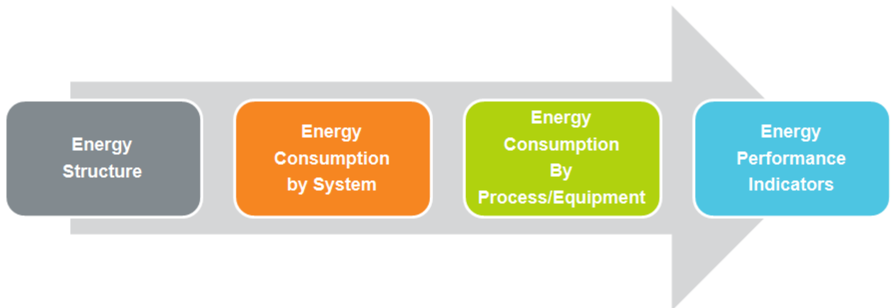
» Highlight energy benchmarks;

» Set energy targets; and

» Design an efficient energy management platform

2.4.1 IDENTIFICATION OF ENERGY FACTORS

Identifying key energy performance indicators is vital for the planning process, as



it provides managers with a clear picture of how their company uses energy and can highlight ways to manage resources better.
The manager's first step is to determine the energy consumption "structure" of his or her company, in other words, what energy resources does the company need to run its operations, be it gas, coal or electricity (see example below).

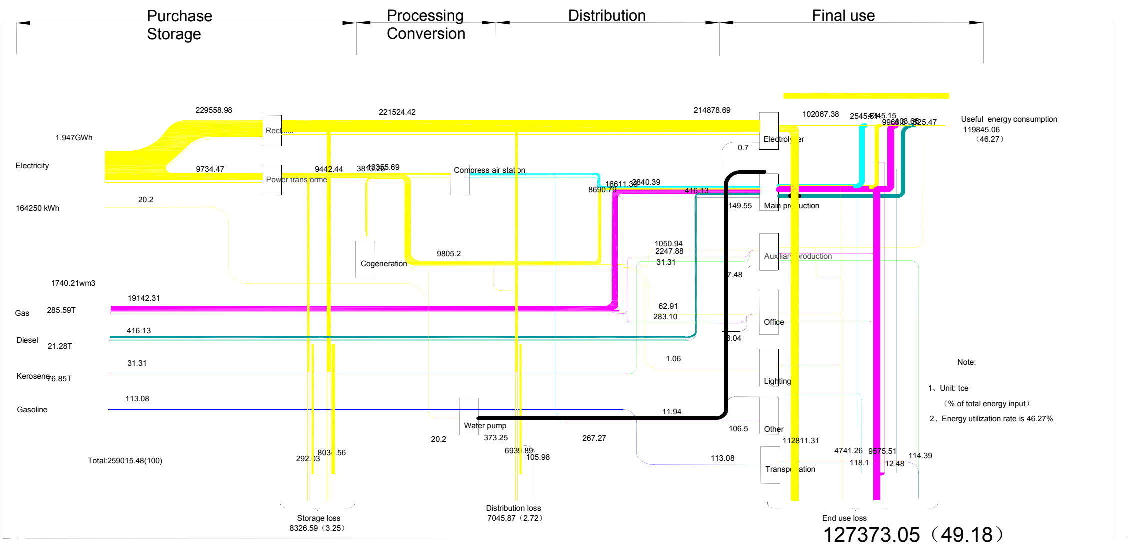
Energy Consumption of Company A

Item	Natural gas (10,000 m3)	Kerosene (t)	Diesel oil (t)	Power purchased (10,000 kWh)	Power generated (10,000 kWh)	Compressed air (10,000 m3)	Surface water (10,000 t)	Total energy consumption (tce)	Recycled (tce)	Actual consumption (tce)
Actual amount	1711.52	14.80	297.54	182825.66	2780.84	62.34	164.06	—	—	—

Conversion to standard coal	10832.21	21.78	433.55	224692.74	3417.65	22.44	200.81	239621.18	3640.91	235980.27
%	4.52	0.01	0.18	93.77	1.43	0.01	0.08	100.00	1.52	98.48

Next a manager should identify the basic systems within their companies that consume energy, such as air conditioners, lighting systems, refrigerators, etc. Then, managers need to look at manufacturing processes that consume energy. Once overall energy use is defined, the manager should design an energy flow chart (see below) based on their overall assessment of the company's energy consumption. The chart should include a detailed analysis of energy usage through the company, highlighting which equipment consumes the most energy. To correctly make this analysis, energy managers need feedback from employees, including factory line managers and technical supervisors.

Fig 1-3 Energy flow



The goal of this process is to allow an energy manager to identify the company's key energy performance indicators, provide top management with a prognosis of the company's energy consumption, and offer recommendations on energy-saving technology.

After identifying the key performance indicators, managers can apply the following principles:

» Ensure compliance with the relevant laws and regulations that apply;

» Ensure a safe working environment;

» Technical feasibility;

» Economic feasibility;

» Energy saving;

» Prioritize low-cost/no-cost solutions.

Table: Energy Performance Indicator

Energy consumption process	Energy consumption asset/equipment	To be eliminated by law or not	Status	Energy factor	Technical feasibility 1-10	Economical feasibility 1-10	Adverse impact (safety, quality, environment) High, Medium, Small, No	Assessment result A: maintain B: control with high priority C: to be studied D: no measure	Related division
Air conditioning	Central air conditioner	No	No control by area, time, and climate	Seasonality	9	9	No	B	Office building Workshop
				Heat/cool air demand varies in different area and time	7	8	No	B	

2.4.2 LAWS, REGULATIONS, AND OTHER REQUIREMENTS

Managers should update their energy performance indicator table on a regular

basis to make sure it's in line with the latest energy regulations and to help in updating targets for their company's future energy strategy. They should also keep a library of applicable rules and regulations.

List of laws and regulations on energy management systems

No.	Laws, regulations, and requirements	Issued by	Date of issuance and implementation
1	Energy Conservation Law	Standing Committee of the National People's Congress	Issued on October 28, 2007 and implemented on April 4, 2008
2	Measures for the Supervision and Administration of Energy Measurement	State Administration of Quality Supervision	Issued on July 22, 2010and implemented on November 11, 2010
3	Measures for the Electricity Demand-Side Management	National Development and Reform Committee, Ministry of Industry and Information Technology, National Energy Administration, Ministry of Finance, State-owned Assets Supervision and Administration Commission, and State Electricity Regulatory Commission	Issued on April 11, 2010 and implemented on January 1, 2011
4	General Principles for Equipping and Management of Energy Measuring Instruments in Energy-consuming Units	State Administration of Quality Supervision	Issued on June 2, 2006 and implemented on January 1, 2007
5	Requirements on Energy Management System	State Administration of Quality Supervision	Issued on March 11, 2009 and implemented on November 1, 2009

6	Notice of the State Council on Further Strengthening the Elimination of Backward Production Capacities	State Council	Issued and implemented on February 6, 2010
7	The First List of Outdated Mechanical and Electrical Equipment (Products) with High Energy Consumption	Ministry of Industry and Information Technology	Issued on December 4, 2009
8	Renewable Energy Industry Development Guidance Catalog	National Development and Reform Committee	Implemented on November 29, 2005
9	Technical Guiding Catalog of Cleaner Production of National Key industry	State Environmental Protection Administration	Implemented on November 27, 2006
10	List of Recommended Energy-saving Mechanical and Electrical Equipment (Products) (1st batch)	Ministry of Industry and Information Technology	Issued on May 27, 2009
11	List of Recommended Energy-saving Mechanical and Electrical Equipment (Products) (2nd batch)	Ministry of Industry and Information Technology	Issued and implemented on August 16, 2010
12	Measures for Supervision and Management of High Energy-consuming Special Equipment	State Administration of Quality Supervision	Issued on July 3, 2009 and implemented on September 1, 2009

No.	**Standard**	**Issued by**	**Date of issuance and implementation**
1	Technical guides for evaluating the rationality of heat usage in industrial enterprise (GBT3486-1993)	State Bureau of Technical Supervision	Issued on June 19, 1993 and implemented on June 1, 1994
2	General principle of energy audit on industrial and commercial enterprise (GBT17166-1997)	State Bureau of Technical Supervision	Approved on December 22, 1997 and implemented on October 1, 1998
3	Guides for the power transformers energy saving operation in factories and mines (GBT13462-2008)	State Bureau of Technical Supervision	Approved on May 27, 2008 and implemented on January 1, 2008

2.4.3 SETTING ENERGY MANAGEMENT BENCHMARKS

Managers should set energy efficiency benchmarks that measure consumption and the number of energy consumption assets in operation. Such benchmarks allow companies to compare their energy management systems against best practices in China and abroad. The benchmarks also allow companies to compare their energy efficiency results against national standards, such as the clean production standard or China's energy-saving technologies policy. (Please see the example below of a benchmark on net coal consumption identified in China's Policy Outline for Energy Conserving Technologies).

Benchmark for coal consumption per gram

A coal-fired power plant consumes 390g coal for each kWh electricity generated.

Benchmark: The Outline of China's Policies on Energy-saving Technologies set coal consumption to 360g per kWh electricity by 2010, compared to 392g in 2000, with power consumption rates coming down to 5.1% by 2020 from 6.28% in 2000.

2.4.4 ENERGY TARGETS AND INDICATORS

Energy managers that are aware of their company's energy performance rating are in a better position to track energy and water consumption, and set targets and indicators (Please see the example below). As a result, they can improve policies, identify areas that need improvement, and measure the investments required for facility upgrades.

2.4.5 ENERGY MANAGEMENT PLAN

Energy management plans should be prepared on the basis of expert opinion and suggestions from front-line employees, bearing in mind the:

Target: Reduce unit coal consumption of boilers

Indicator: Reduce coal consumption per ton by 5% in 2012 (with that of 2010 as baseline).

Measures: Install steam accumulator; check CO and CO2 smoke levels and install combustion control device.

Division in charge: Engineering
Person in charge: Maintenance Supervisor

Investment: RMB 200,000
To be started by: 2012.5
To be completed by: 2012.7

» Purpose of the plan
» Measures to take and persons in charge
» Timetable for the plan
» Performance evaluation/assessment methods and indicators
» Rules for adjusting the plan in case of emergency

2.5 IMPLEMENTATION AND EXECUTION

The second step of PDCA cycle is "Do", which means implementation of the plan, which includes:

» Competence building and information sharing among employees;
» Stakeholder participation (optional according to international guidelines);
» Document and record control;
» Operation control; and
» Emergency preparedness and response

2.5.1 COMPETENCE BUILDING AND INFORMATION SHARING

Companies should ensure energy managers and any other staff members involved in the energy management process have the required management and technical skills to execute the plan. Providing all employees with energy management training will make them more aware of better energy consumption practices, and will allow companies to receive valuable feedback from front-line employees as well as staff proposals. Companies can also provide their employees with incentive policies and awards for helping to reduce energy consumption and improve energy saving practices.

According to the Energy Conservation Law, units with large energy consumption must submit an annual report to government agencies in charge of energy saving activities.

Such reports should cover energy consumption, energy efficiency, whether targets are achieved, energy saving benefit analysis and energy saving measures.

2.5.2 STAKEHOLDER PARTICIPATION (OPTIONAL)

To ensure their company's energy performance is constantly improving, energy managers should involve a variety of stakeholders, including their employees, suppliers, customers, local government staff, and members of the local community, in establishing their energy management system.
Furthermore, stakeholder participation can help the company establish mutual trust with local communities, comply with local regulations and reduce energy-related risks and conflicts. Larger companies often have a stakeholder participation scheme already in place, but smaller companies, given their size and financial limitations, typically do not.

To establish stakeholder involvement, SMEs should advertise their plans to establish an energy management system; explaining how the plan can benefit the local community, the government and their customers. This would help rally support from stakeholders and increase their involvement in the company's energy management policies, particularly by employees. Since, it could act as an incentive for staff to contribute to the company's energy-saving schemes.

2.5.3 DOCUMENT AND RECORD CONTROLS

Energy management system documents should be prepared according to the following guidelines:

» Documents must be prepared by an energy manager;
» Documents must be approved by authorized personnel before publishing;
» Documents must show the date of issuance or date of revision and include

information on the personnel who approved them;

- » Documents must be updated regularly, with invalid or abolished articles deleted and properly marked;
- » The latest documents must be available to relevant divisions and personnel; and
- » Documents must comply with national laws and regulations, covering all energy management system requirements.

Case example: A coking plant's coal requirements

Purchased coal must have good coking properties and conform to the following:

The ash content should be less than 10% and cannot exceed 12.45%.

The sulfur content should be less than 1.5%, or 2.5% in the case of rare coal such as fat coal.

The moisture should be less than 12%.

The phosphorus content of pig iron should be lower than 0.01% ～0.015%.

There are two kinds of energy management records, and these include:

- » **Internal records,** which comprise records on equipment maintenance, energy statistics, energy factor registration forms, internal reviews, training, improvement plans, etc.
- » **External records,** which comprise the energy audit report, archives on key energy-consuming equipment, etc.

2.5.4 OPERATION CONTROLS

Companies should follow the operation controls of their energy management systems closely, particularly the following:

- » Incorporating sustainability policies into their product development with the goal of reducing energy consumption, improving energy efficiency, and using reusable resources without compromising product quality, safety, or cost.
- » Consider energy saving before purchasing equipment to avoid acquiring equipment that consumes excessively high amounts of energy. Also, by optimizing the operating condition of existing equipment, and conducting maintenance on a regular basis, companies can reduce damage to equipment that could contribute to higher energy consumption.
- » Create a company standard for purchasing energy, including a selection of preferred energy suppliers, measurements and verification of energy sources, transportation and storage, etc.
- » Companies should measure, record and evaluate the energy consumption of their production and service processes so that they can eliminate outdated processes.

Case example: Energy rules of company X.

In the summer, office temperatures should be set at 26 °C, with an air volume of five m3/hp.

The temperature of workshops should be kept at 28 °C, with an air volume of 20 m3/h.p

2.5.5 EMERGENCY PREPAREDNESS

Companies should consider making emergency plans based on real life situations that could affect their energy systems.

2.6 INSPECTION AND CORRECTION

"Check", the third step of the PDCA cycle refers to inspection and correction of energy management plans.

2.6.1 MONITORING AND ASSESSMENT

Monitor energy management results, as well as key performance indicators (KPI) based on the company's energy-efficiency benchmarks, using an energy assessment form such as the one below.

EXAMPLE: Energy-saving Statistical Form of Company A

2010 Fodder Plant Energy Saving and Emission Reduction Statistical Form													
Company name:		Date:											
		Energy consumption per ton and production volume				Compared with that of 2009 (+/-)				Increased by (%)			
		Power consumption (kWh)	Coal consumption (ton)	Oil consumption (L)	Production volume (10,000 RMB)	Power consumption (kWh)	Coal consumption (ton)	Oil consumption (L)	Production volume (10,000 RMB)	Power consumption (kWh)	Coal consumption (ton)	Oil consumption (L)	Production volume (10,000 RMB)
Mixed fodder	Powder												
	Granular												
Condensed													
Additive premixed													
Average													
Person in charge: Filled by: Tel:													

2.6.2 MAKING AN IMPROVEMENT PLAN

Prepare an improvement plan based on monitoring and assessment results. The aim is to:

- Correct non-conformities;
- Take preventive measures against non-conformities; and
- Assign a person in charge of following up and ensuring that improvements are implemented.

EXAMPLE: Non-conformity report of Company A (Corrective Actions Form)

Division audited:
Results The items above do not conform to _______________ and are _________________ non-conformities. Auditor/date:
Receipt by manager of division audited: Date:
Cause analysis and corrective actions: To be completed on: Manager of division audited: Auditor: Approved by:
Implementation of corrective actions: Manager of division audited: Date:
Effectiveness of corrective actions: Auditor/date:

2.7 MANAGEMENT REVIEW

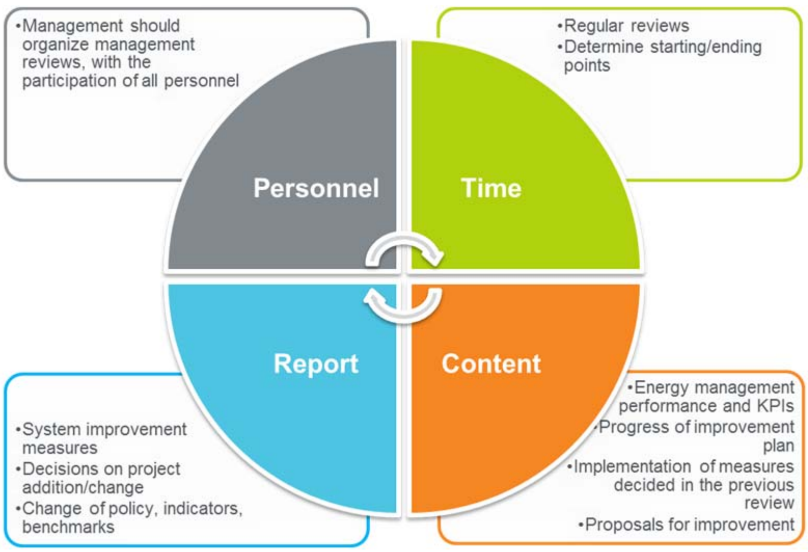
The last step of the PDCA cycle is "Action", which refers to the management review.

It should be conducted at an annual management review of the company's energy management system. The review should:

» Include all personnel involved in energy management.

» Look at how the energy management system has performed and examine KPIs; assess the progress of any improvement plans; ensure previous review measures were implemented, and include proposals for improvement.

» Include a report detailing any improvements as well as proposals for changes or additions to the system, or changes in policies, performance indicators, or benchmarks.



Energy Audit

1. Overview

1.1 WHAT IS AN ENERGY AUDIT?

Conducting regular energy audits, where auditors inspect, analyze and evaluate a company's energy consumption, allows energy managers to assess how much energy their company uses and to pinpoint opportunities for potential energy and cost savings. An audit is only useful, however, if energy managers can implement their auditors' recommendations.

Energy audits compare the energy consumption and energy efficiency of different companies in the same industry by looking at comprehensive energy consumption, increase of energy consumption, and energy consumption per unit product etc.

Production at every company includes several processes and each process consumes energy. Thus, a company's production process is intrinsically linked to its energy consumption.

When examining a company's process energy consumption, it is necessary to analyze relevant factors, including the quality of raw materials, equipment used, type of energy used and subjective factors such as staff quality, production arrangements, and the condition of equipment.

In the case of processes that consume a large part of the overall energy used in production, it is necessary to conduct quantitative analysis on factors to find ways to resolve the issue.

1.2 CONTENTS OF AN ENERGY AUDIT

- **Energy management systems** - review its compliance with national laws and regulations, the quality of its systems and policies and compare production levels to energy savings.
- **Consumption and flow of energy** - accounts for energy input, storage, conversion, waste, sales and consumption.
- **Statistics** - measures instruments, calibration, measuring rate, and instrument management. This also includes the scope of energy report, frequency of submission, breakdown level, depth of analysis, etc.
- **Consumption indicators** - only accounts for a company's energy consumption, but not its energy inputs.
- **Operating efficiency of equipment** – assesses to what extent company equipment makes efficient use of energy.
- **Energy consumption during manufacturing** - includes consumption per unit of output value, per unit of product, direct and indirect energy consumption and energy consumption per comparable unit product.
- **Energy cost indicators** - multiplies energy consumption by energy price.
- **Energy savings** - differentiates actual energy consumption and benchmark consumption.
- **Economic analysis of energy-saving projects** – makes a comparative analysis of energy costs for similar products and conditions.

1.3 ENERGY AUDIT LAWS AND REGULATIONS

- Energy Conservation Law
- Program for Energy Saving of One Thousand Enterprises
- General Principles of Energy Audit on Industrial and Commercial Enterprise (GB/T17166—1997)
- General Principles of Energy Monitoring Technology (GB/T15316)
- General Principles for Calculation of Thermal Efficiency of Equipment (GB/T2588—1981)
- General Principles for Calculation of Comprehensive Energy Consumption (GB/T2589—1990)
- Guideline on Measuring and Testing Energy Consumption (GB/T6422—1986)
- Energy Saving Calculating Methods (GB/T13234—1991)
- Guideline on Energy Management in Industrial Enterprise (GB/T15587—1995)

Power Consumption Knowledge

A transformer consumes power even when there is no current running through it. The only way to avoid this is to turn off the power switch.

As long as there is a current, transformers, cables, and other electronic equipment consume power.

Stand-by Power Consumption

Most electrical equipment cannot be switched off completely without being unplugged, thus even if power is switched off, the equipment still uses electricity. A computer on standby mode consumes about 7.5W of power. If it is turned off, but the plug is not removed from the socket, it still consumes 4.81W of power.

The standby power consumption of a computer is worth 50kWh of consumption a year. Considering the amount of equipment in a factory, the potential to waste power is significant.

- General Principles for Equipping and Management of Energy Measuring Instruments in Energy-consuming Units (GB/T17167—2006)
- Technical guides for evaluating the rationality of heat usage in industrial enterprise (GB/T3486—1993)
- Technical guides for evaluating the rationality of power usage in industrial enterprise (GB/T3485—1993)
- Technical guides for evaluating the rationality of water usage in industrial enterprise (GB/T7119—1993)
- Statistical method of energy balance in enterprises (GB/T16614—1996)
- Methods of drawing up energy balance table in enterprises (GB/T16615—1996)
- Methods of drawing energy network diagram in enterprises (GB/T16616—1996)

2. Key Reasons for an Energy Audit

2.1 CORPORATE ENERGY SAVING

Electricity is the most commonly used form of energy. If the use of this is managed correctly it can therefore help many companies cut their energy consumption and costs.

Lighting systems, electric motors and drive systems, and heating/cooling systems are the three most commonly used energy consuming systems across all industries, whether large or small. Thus, similar energy-savings strategies can be applied to any size business.

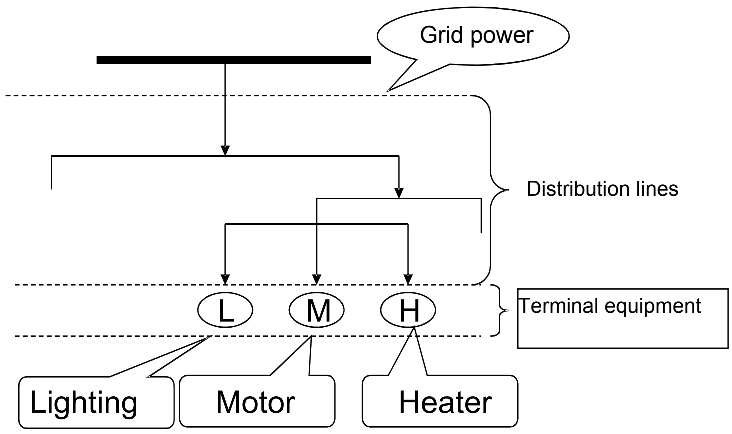


Fig.2-1 Power consumption of a company

Before devising a strategy to cut electrcity use, an energy manager must answer ***three questions***:

- How and where are the power outlets that consume energy and how much is consumed at each outlet?
- How much should each power outlet consume?
- How can energy consumption be reduced?

To answer these questions, it is necessary to measure power consumption, and to understand ***how and when power is consumed.***

Direct consumption is energy consumed during manufacturing. **Common use**

consumption is energy consumed during office hours. **Auxiliary energy consumption,** is additional energy consumed apart from central production processes and includes standby power generation, and other backup systems. (See illustration below).

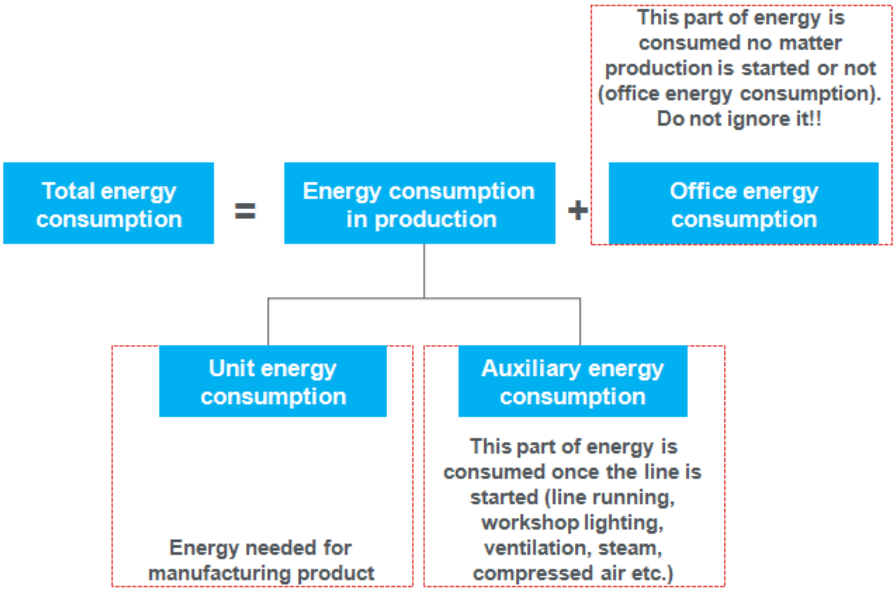
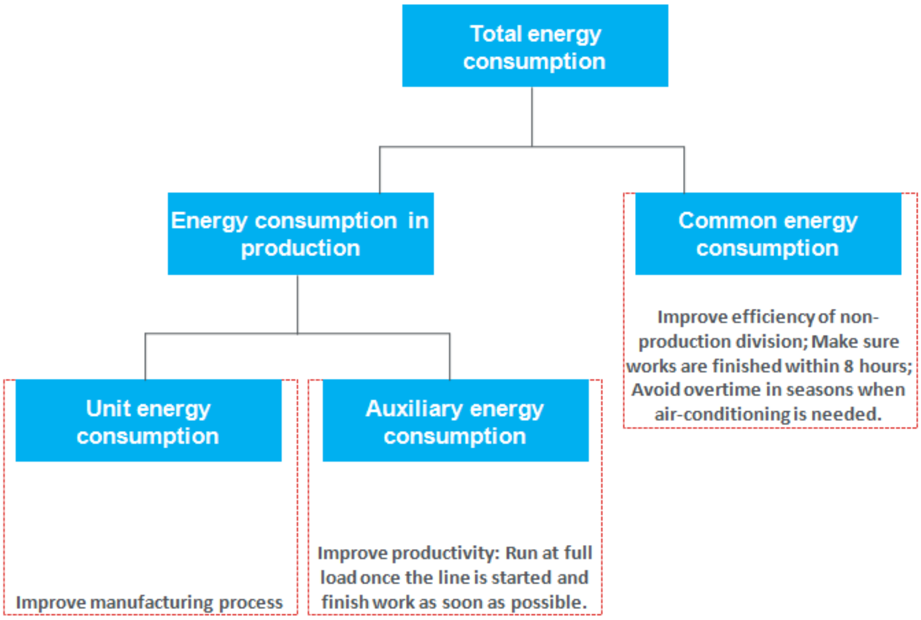


Fig. 2-2 Energy structure

Fig. 2-3 How to Save Energy



2.2 ENERGY MEASUREMENT

Measuring energy data is a key component for implementing an energy management plan. To be done effetively a manager needs to:

» Establish an energy data measurement system;

» Designate staff in charge of monitoring energy use;

» Ensure proper use of energy measuring instruments and ensure safety of meters; and

» Provide energy data in a complete and timely manner.

Larger companies usually have an independent energy measurement division or designated personnel in charge of energy measurement, while smaller companies designate an energy manager to conduct the task of measuring energy consumption.

Designating staff members to implement energy measurement is important to creating an effective system.

Preparing a document that details ways the company measures energy is essential. This document includes information on monitoring data, as well as the staff members responsible for monitoring energy supply and consumption.

It also contains information on the instruments used to monitor energy consumption, details on storage, disposal, purchase, maintenance and calibration. It should also include a list of all equipment that measures energy consumption, detailing the name, model, manufacturer, serial number and date of calibration of the monitoring equipment (See below).

List of Energy Measuring Instruments

No.	Name	Model	Precision degree	Scope of measurement	Manufacturer	Delivery number	Management number	Location of installation (workshop, line, equipment) and usage (energy measurement, self-inspection, energy quality analysis)	Condition (qualified/allowed to use/forbidden to use)
1	Power meter	DX863-2K	0.5	—	Swiss	67877983	EP-301A01	High-voltage room, 1F, 301 Substation: Shenhua No.1 line	Qualified
2	Power meter	DS862-2	0.5	—	Wuxi Weida	1685	EP-301A03	High-voltage room, 1F, 301 Substation: Shenhua	Qualified
3	Vortex flowmeter	DN200	2.5	—	Shanghai Henghe	9803106	FQ-1100	152 pipe rack, Meiya Steam	Qualified
4	Electromagnetic flow meter	MAG-XE	0.5	—	ABB		WA-001	103C South Gate, tap water inlet of the factory	Allowed to use
5	Turbine flow meter	DN200	1	—	Shanghai Henghe		FQ-1350A	152 pipe rack, Meiya Softwater	Qualified
6	……	……	……	……	……	……	……	……	……

Although measuring energy data only reflects "overall consumption" rather than energy efficiency, it is still fundamental to evaluating energy efficiency and energy-saving opportunities.

Companies should measure energy consumption by taking into account:

» Overall energy consumption.

» Energy consumption of power lines and departments

» Energy consumption of office and production equipment.

Alternatively, companies can measure power by:

(1) Measuring average power over a period of time:

» For a system with constant power: Power consumption = actual power X working hours

» For a system with variable power: Power consumption = average power X working hours

(2) Deciding where to install an electric power meter depends on whether the:

» Equipment consumes large amounts of power or power consumption fluctuates;

» Systems require modification to make them more energy efficient; and

» Lines/departments that are subject to energy assessment and evaluation.

2.3 ENERGY-CONSUMING EQUIPMENT

Energy managers should identify office and production equipment that consume the most energy. According to the Principle for Equipping and Managing the Measuring Instrument of Energy Units (GB17167-2006), these pieces of equipment often consume power that is above the limit specified in Table 2-1.

Table 2-1 Limits of power consumption (or power) of main energy-consuming equipment

Energy type	Electricity	Coal	Crude oil, product oil, LPG	Heavy oil Residual oil	Gas Natural gas	Steam Hot water	Water	Others
Unit	kW	t/h	t/h	t/h	m^3/h	Mw	t/h	GJ/h
Limit	100	1	0.5	1	100	7	1	29.26

A company can compare Table 2-1 and the criteria below against their own office and production equipment. Equipment is problematic if it:

» Has estimated annual energy consumption above 80,000 kWh;

» Is “major” equipment (large quantity, low unit power); and/or

» Is not operating optimally in accordance with its design.

It is important for managers to hire experts to conduct regular energy efficiency tests on equipment that uses high amounts of energy (See Table 2-2). The tests should be carried out on as many pieces of equipment as possible so managers can gauge the overall energy needs of the company.

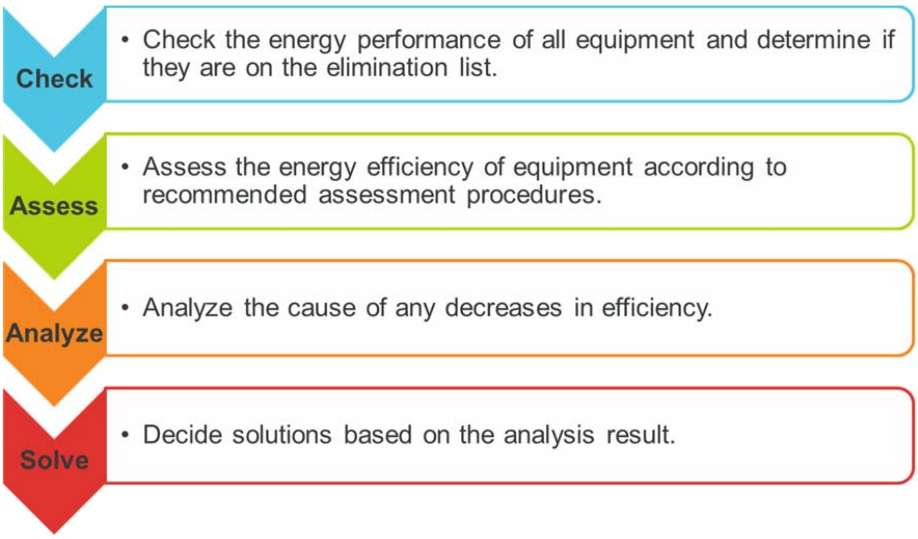
Table 2-2 Sample Energy Efficiency Test Form

No.	Characteristics	Equipment Name	Quantity	Location	Tested efficiency	Design efficiency

1	Over 500 lamps with annual lighting time more than 4,000 hours					
2	Over 1,000 lamps with annual lighting time more than 2,000~4,000 hours					
3	Annual power consumption of equipment >80000kWh					
4	Annual power consumption of equipment 20000—50000kWh Large deviation from design condition					
5	Boiler					

3. Energy Diagnosis Methods

3.1 MEASURING THE ENERGY EFFICIENCY OF COMPANY EQUIPMENT
Managers can measure the efficiency of all equipment using the following steps:



Potential challenges to conducting energy efficiency tests

Tests are expensive because they have to be conducted by experts and senior executives might be reluctant to replace equipment if there is insufficient data.

Managers may be biased if low equipment efficiency is due to bad management yet it is difficult to evaluate the investment return of such tests.

Check: Managers should identify whether their equipment is listed under the Guiding Catalogue of Industrial Structure Regulation (2011) or the Outdated Mechanical and Electrical Equipment (Products) with High Energy Consumption (first batch). Many companies are unwilling to retire old and outdated equipment, especially if it still works, not realizing that such equipment causes companies to incur additional costs in the long run.

Assess: Managers should also evaluate equipment that is not yet outdated to determine its energy efficiency based on national and international standards.

Analyze: Low operating efficiency is caused by:

1 Low quality equipment, including obsolete equipment that is listed in the “Eliminated Products Catalog”;

2 Improper service maintenance and operation; and

3 Process requirements that render equipment less efficient.

Solve: To correct efficiency problems managers should:

4 Replace obsolete equipment with new energy efficient models;

5 Improve energy management, including the establishment of equipment operation and maintenance policies; and

6 Integrate energy-saving technologies into the manufacturing process at a system level.

Case study of an electronics factory

At an assembly workshop in an electronics factory, 80 percent of total energy consumption goes towards auxiliary uses. This is largely because the workshop runs 8-hour shifts even though productivity is low and there are insufficient orders.

Suggestions:

Maintain higher productivity levels with the aim of completing production in six hours rather than eight. This will save the company 276 kWh of power (RMB 220) every day.

The remaining hours can be used to train operators.

Switch to night shifts as this could help reduce air-conditioning costs, since the price of electricity is significant lower at the night than in the daytime. (allowing for a reduction of 80 percent of energy costs.)

3.2 ENERGY STRUCTURE EVALUATION

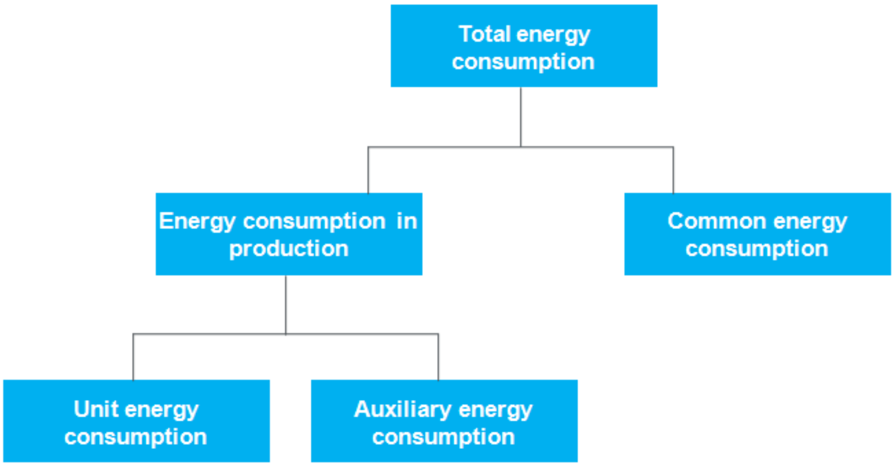


Fig. 2-4 Energy structure

As shown in the figure above, direct consumption, auxiliary consumption, and common consumption are independent parts of overall energy consumption. Reducing any of these three types of consumption would reduce overall energy consumption.

Auxiliary energy consumption energy-saving solutions:

» Maintain high-efficiency production

» Improve energy efficiency of high cost auxiliary equipment

» Reduce working hours

Direct energy consumption energy-saving solutions:

» Reducing direct energy consumption is relatively difficult. Generally, it can be done by reducing temperature, pressure, speed and flow of the production process.

» Conduct a systematic production process analysis.

Common energy-saving solutions:

» Increase work efficiency

» Reduce overtime if possible

» Create awareness of energy-saving management

3.3 SYSTEM ANALYSIS METHOD

Managers can conduct a system analysis of their energy systems to determine how these systems interact. For example, a manager might look at how electrical and water supply systems, function with the company's energy system as a whole. (Please see the case study below.) The aim is to identify energy-saving opportunities by identifying how different sets of electrical systems function together. The disadvantage of using this method is that testing requires advanced technical equipment and high-level technical expertise, which most SMEs would be unable to afford.

Case study: Waste water Treatment Plant Pump

A pump in a wastewater treatment plant (motor power: 11kW, flow: 100m^3/h, head: 25m) had a measured efficiency rating of 95 percent and measured input power of 8.25kW. Although appearing stable, an inspection revealed that a valve used for satisfying the need of discharge flow (100 m^3/h), was only opened by 1/3. After the valve was fully opened, the flow exceeded 10 percent of what was needed, and the efficiency dropped to 64 percent.

From an efficiency point of view, any non-fully opened valve in the pipeline is considered a waste of energy. The solution was to replace the pump with another that had a 100 m^3/h flow, 15m head, 7.5kW motor power, and 6kW input power. Annual energy savings = 2.25×24×350 = 18,900 kWh. The investment was paid back in half a year.

3.4 CLASSIFICATION METHODS

Managers seeking to reduce energy consumption can identify different ways that their companies can save energy. They can do this by using a classification method, which highlights (into a line diagram, as below) areas where the company can improve their use of energy, making energy waste easier to address.

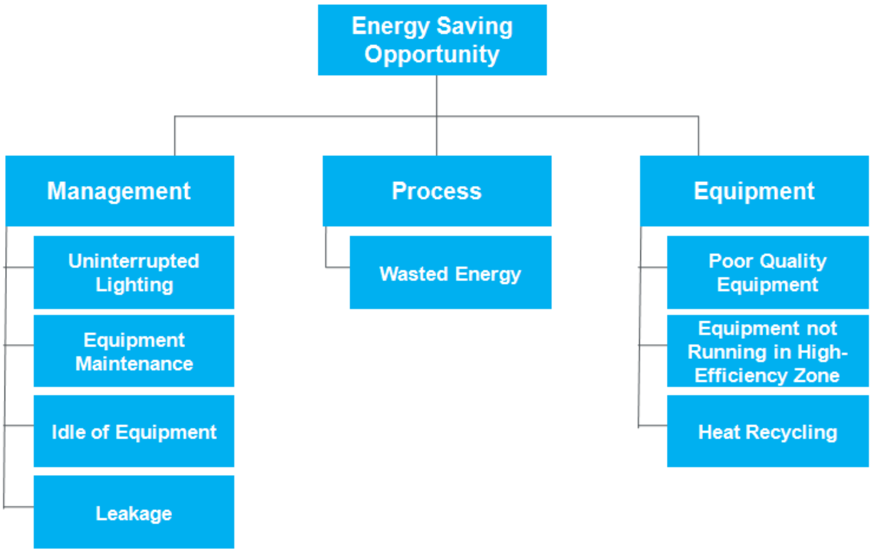


Fig. 2-5 Classification Method

3.4.1 REDUCING WASTE

To curb energy waste, managers must identify potential areas of waste, including:

- Unnecessary uninterrupted lightening;
- All kinds of leakage;
- Equipment that consumes energy during non-working hours;
- Times when production capacity falls below equipment capacity; and
- Equipment inefficiency as a result of poor maintenance.

How can companies reduce energy waste through better management?

- Managers should establish a corporate culture that encourages the elimination of wasted energy;
- A patrol team can be set up to identify energy waste throughout the company;

» Conduct energy-saving training; and

» Implement incentive policies to award employees that conserve energy.

3.4.2 PROCESS ENERGY SAVING

Managers may also implement a process energy saving method to increase energy efficiency. This aims to optimize production processes by measuring areas where the company wastes energy, such as;

» Over-lighting (over-lighting in a workshop of a Fortune-500 company is typically around 400,000 kWh);

» Excessive use of heat or pressure. One well-known company, for instance, its energy use by 40 percent by reducing the amount of compressed air pressure it used for cleaning parts to 0.3MPa from 0.58MPa;

» Unnecessarily low temperatures. A food processing plant, for example, saved 10 percent on its air-conditioning costs (RMB 200,000/year) by increasing its workshop temperature from 22 degree Celsius to 24 degree); and

» Excessive consumption of high quality water or compressed air.

Why are there several opportunities to enhance energy savings in the production process?

In most cases, production process parameters for equipment are designed to satisfy the "maximum production load." But when it comes to actual production, the loads are usually processed slower, making parameter designs redundant. Equipment manufacturers often fail to consider energy saving in their designs, causing equipment to consume more energy than is necessary.

Philosophy for process energy savings: Any energy supply with unnecessary output, no matter how efficient, is a waste.

Why process energy saving has the highest effect: To reach the terminal, energy first passes through the transformer, conversion devices and the distribution equipment.

Input energy = output energy/η

η: system efficiency. Since η is less than 1, by reducing output energy, it is able to achieve a significant energy saving effect. For example, if the output of a compressed air system with an efficiency of 0.3, comprising five components, including power supplies, compressors, air processing equipment, distribution pipelines and pneumatic tools, is reduced by 1kW, input energy will fall by 3.33kW -- a significant energy saving.

Process energy saving is a low cost way of improving the quality of products, while reducing energy consumption. To implement this process, managers should:

» Identify how much energy each business process consumes and find ways to control the system's parameters, including the air temperature, atmospheric pressure, etc.

» Use a team of engineers to control energy flows through production systems. As energy flows from higher temperatures to lower temperatures, it creates heat flows; and it moves from higher pressure to lower pressure, it causes expansion.

3.4.3 MAXIMIZING THE EFFICIENCY OF EQUIPMENT

There are two key issues to consider when trying to save energy:

- Design efficiency reflects maximum efficiency and cannot be achieved in actual production.
- Energy-saving technology resolves the issue when equipment is "operating in the low efficiency zone", but it is not a remedy for poorly maintained equipment. Equipment maintenance is thus vital and should take place on a regular basis, as per the requirements of its maintenance manual.

To enhance energy saving on equipment, managers should:

- Inspect the condition of equipment regularly to avoid energy waste caused by poor maintenance and avoid: (a) the loss of heat transfer in heat exchangers; (b) blockages in the fuel filters; and (c) overloading of lubrication systems, among other issues. One company found a filter in a compressed air system was blocked, causing a 146kW overload of the power generator. The air generated by the compressor, meanwhile, only amounted to 18m/min.
- Consider whether the design specifications of the company's equipment causes low energy efficiency, and if that is the case, whether the company can replace it with one that is a better fit for its needs.
- As an alternative to replacing equipment, companies can install inverters or other energy-saving devices. Although doing this saves energy to some extent, it does not reduce costs or overall energy consumption. The example below demonstrates this point.
- Consider adding a frequency converter (see side bar) to increase the frequency cycle of fans or pumps operating in alow efficiency zone; to improve systems with fluctuating pressures or with compressors running constantly.

Frequency Conversion Devices

Equipment that has a driver motor can reach its intrinsic efficiency only when it runs under conditions for which it was ideally designed.

When selecting equipment, companies usually consider the maximum power required, but most of the time, the equipment doesn't run at its maximum power and so is not as efficient as it could be.

This is where frequency conversion technology comes in to play. Frequency conversion technology can make fluid machines run close to their design efficiency, but this technology cannot make the efficiency of motor systems any higher.

Examples of Frequency Conversion

Before

After

Fig. 2-7 Frequency conversion and constant voltage control project for the power station of a company

A company invested RMB 50,000 in a frequency conversion and constant voltage control project for its power station. The new system reduced power consumption by 6500 kWh and saved the company RMB 5,200 a month.

Fig. 2-8 Elevator network controller

By introducing an elevator network control system based on frequency conversion technology, a company saved 6,000 kWh power per month, equivalent to monthly savings of RMB 4,800 (based on a price of RMB 0.8/kWh).

Energy Savings for Key Energy-Consuming Systems

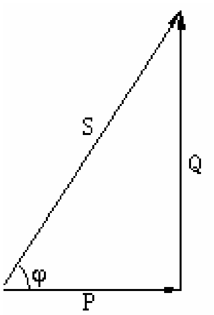
1. Power Distribution Systems

1.1 ENERGY DIAGNOSIS: POWER DISTRIBUTION SYSTEMS
A company's distribution systems network carries electricity from the transmission system and delivers it to its equipment and factories. Typically, the network includes low-voltage (less than 1 kV) distribution wiring and medium-voltage (less than 50 kV) power lines and transformers, which engineers can regulate to reduce the voltage of power distribution to the company. Enhancing equipment and distribution efficiency ensures higher energy savings and reduces power used during the distribution process.

Power Factor

The power factor of an alternating current (AC) electric power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit. It is a dimensionless number between 0 and 1. AC has two kinds of energy: "active power", which is converted into heat, light, mechanical energy, or chemical energy; and "reactive power", which is used to build magnetic fields for energy conversion. AC is converted into magnetic field energy and then back to electric power, and again to magnetic field energy, repeatedly. It appears redundant when compared with active power, but without it, magnetic fields would not exist and motors and transformers would not work.

To draw a power triangle requires using apparent power (S), active power (P), reactive power (Q), effective voltage $\overline{U}$, and effective current (I)



Fi.g3-1 Power triangle

$P = S \cdot \cos\varphi = \overline{U} I\cos\varphi \quad Q = S \cdot \sin\varphi = \overline{U} I\sin\varphi \quad S = \overline{U} I$

The unit of active power is "watt" or "kilowatt". The unit of reactive power is "var" or "kilovar" and the unit of apparent power is "VA" or "kVA". The phase angle is the angle between φactive power and apparent power, also known as the "power factor angle". "cos"$\varphi$is active power (P) divided by apparent power (S), which is the "power factor".

- The power factor is a number between 0 and 1. At 0, energy flows are entirely reactive, whereby stored energy returns to its source on each cycle. In contrast, when the power factor is equal to 1, all the energy is consumed by the load and none returns to the source, resulting in over-utilization of energy.
- Technical apparatus can be used to test motors and circuits to determine the optimal power factor of each load.
- The recommended power factor is below 0.95.

1.2 ENERGY-SAVING MEASURES FOR POWER DISTRIBUTION SYSTEMS

- Select **cable sections** according to the economic current density. The economic current density is closely related to the annual operating hours of cables. Considering the large amount of data and calculation required to determine the economic current density, a comparison method is commonly adopted by industrial companies.
- An increase of the **operating voltage** helps to improve power quality and reduce line loss. By increasing voltage by 10 percent, a subsequent 18 percent decline in line loss can occur.
- Reducing reactive currents and increasing the **power factor** of a line is an effective way of reducing energy waste. At a constant voltage and current, the higher the power factor, the higher the active power will be. A chemical factory, for instance, installed a 1,500 kVA transformer. The initial requirements were 1,160 kVA with a power factor of 0.70. The load percentage of the transformer was 78 percent (1160/1500=77.3%). To increase the load, but avoid fines charged by the power agency, the factory needs to add 438kVAr reactive power compensation to the motor load. This subsequently increased the factor to 0.90 and reduced power to 900 KVA, which is the vectorial sum of KW and KVAr.

How to select a transformer

Stick to the economic operation principle by selecting transformer capacities according to the calculated capacity (this principle can be applied to new factories or for expanding existing factories.)

Adjust or replace transformers according to the actual load rate. The load rate of a stand-alone transformer should be 70 to 80 percent. In the case of a transformer network, some loads should be transferred and several transformers should be stopped (this applies to existing factories.)

Select energy-saving transformers (S11) to reduce the amount of no-load currents and reactive power losses. It is better to maintain the temperature of the distribution room at 60 °C by installing ventilation equipment.

Note: A 1 °C decrease of a transformer's temperature results in 0.32% reduction of power loss and an 8 °C increase of a transformer's temperature results in a 50% reduction of the transformer's life.

Fig. 3-2 Temperature reading of transformer in power distribution room

Since the load of the 1500KVA transformer is using only 60 percent of its capacity, the factory can add more loads to the transformer in the future.

2. Lighting Systems

2.1 ENERGY DIAGNOSIS: LIGHTING SYSTEMS

Businesses can save money and create a more comfortable environment for their workers by upgrading lighting systems to higher quality alternatives with the use of lighting controls, alternative electrical sources and natural light.

Problems frequently found in lighting systems include:

» **Uninterrupted lightening**: In many cases, office buildings and manufacturing plants are illuminated overnight and on weekends, and sometimes workers operate outdoor lighting during the daylight.

» **Over-illumination** in office buildings due to poor lighting system design;

» **Under-illumination** due to dusty light bulbs, lamp shades or poor quality lighting design and selection;

» **Insufficient use of natural light**; and

» **Use of low-efficient light bulbs**

Energy efficiency can be achieved by:

» **Improving lighting management**: Identify the best ways to use illumination, either through improving the location or the number of hours that illumination is required or find ways to make better use of natural lighting (See figure 3-3 below);

» **Improving energy-saving processes**, by determining the best location for lighting in factories, offices or unoccupied areas; and

» **Selecting equipment that offers maximum energy savings**. For example, a company C throughout the year.

2.2 MEASURES FOR ENHANCING ENERGY SAVINGS IN THE LIGHTING SYSTEMS

Step 1: Decide on the illuminance, which measures the luminous flux spread over a given area.

» Corridor and walkways: 80-120 lux

» Work areas used intermittently: 150-200 lux

» Office areas: 200-250 lux

» General inspection areas: 350-450 lux

» Continuously occupied areas used for the inspection of small parts: 500-600 lux

Recommended Illuminance (LX)

Illuminance (LX)	Area or activity
20-30-50	Outdoor areas, such as corridors, storage areas, staircases, bathrooms, cafes, bars, stations , etc.
30-100-150	Spaces before elevators, receptions, bar counters, indoor agricultural product markets, duty rooms, postal offices, game centers, theatres, station halls, inquiry rooms, diagnosis rooms, paths in supermarkets, etc.
100-150-200	Work areas, such as offices, receptions, tables in hotel rooms, shelves in stores, counters, canteens, kitchens, ticket rooms, rehearsal halls, ticket counters, operation rooms, radiology rooms, etc.
200-300-500	Places requiring low-level visibility, such as reading rooms, design rooms, showcases, exhibition rooms, hair salons, cooking rooms, training halls, exhibition halls for glass, stone, and metal products, etc.
300-500-700	Places requiring medium-level visibility, such as stadiums for gymnastics, tennis, basketball, swimming, wood processing rooms, general fine and rough processing rooms, machine areas, electrical equipment maintenance rooms, etc.
500-750-1000	Places requiring high-level visibility, such as venues for table tennis, Weiqi, and chess games, metal processing factories, fine parts assembly lines, areas for maintenance of precision parts, typing rooms, polishing workshops, etc.
750-1000-1500	Areas requiring very high-level visibility.
1000-1500-2000	Areas requiring special visibility.
>2000	Precision works requiring extremely high-level visibility.

Step 2: Based on decisions made in Step 1, determine the desired power levels, lighting layout and methods for lighting equipment. Add additional lighting when an illuminance of over 500 lux is required.

Step 3: Use energy-saving lighting equipment and controls.

1) LED, T5 are more efficient than previous forms of lighting

Table 4-2 Lamp Comparison

Lamp	Lighting efficiency	Life
Incandescent lamp	720Lm/W	1000-2000hr
Fluorescent lamp T8	55Lm/W	3000-5000hr
Fluorescent lamp T5	85Lm/W	8000-10000hr
LED	150Lm/W	10000-50000hr

As the above table demonstrates, the higher the lighting efficiency, the greater the amount of energy saved. But a comparative analysis of different kinds of lamps with the same luminance is essential, as it provides a better estimation of overall energy efficiency. For instance, at the same illuminance, the T5 fluorescent lamp saves 35 percent more power than its T8 equivalent (the most popularly used type of industrial lighting).

Energy-saving ballasts

The energy consumption of a fluorescent lamp equals includes the consumption of ballast, which is needed to run the lamp. To reduce the energy consumption of fluorescent lighting, both the lamp and the ballast must include energy saving technology.

Table 4-3 Ballasts

Lamp power (W)	Ballast power/lamp power (%)		
	Common	Energy-saving	Electric
<20	40-50	20-30	<10
30	30-4	<15	<10
40	22-25	<12	<10
100	15-20	<11	<10

2) Install reflecting covers (in instances where illuminance levels are insufficient, but would be excessive with an additional lamp).

Reflective covers can reflect light from a lamp to other areas where lighting is needed, increasing illuminance by 25 percent and reducing the number of lamps needed. Furthermore, reflecting covers have a long product life and no adverse effects.

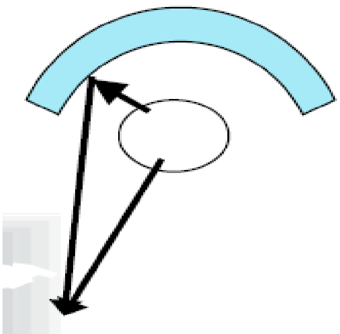


Fig. 3-4 Reflective cover for fluorescent lamp

Step 4: Management methods include:

» Lighting controls to eliminate unnecessary lighting

» Cleaning dirty lamps toimprove light efficiency

» The use of as much natural light as possible

2.3 CASE STUDY: REDUCING ENERGY CONSUMPTION OF AN ELECTRONICS FACTORY'S LIGHTING SYSTEM

Location: Lighting system is in a large-scale electronics factory

The production lines in the factory are located close to windows, and receive enough natural light during the day for production. The lights in the factory and the corridor and product transfer areas cannot be switched off independently. The lighting in most factories is designed to satisfy the highest illuminance requirement, and thus evenly distributed across the workshop.

Energy-saving measures include:

- Evenly distributed lighting: 900×3x2700
- Total power: (36x2)×2700x102.6kW (T8 lamp)
- Average illuminance of 50 points: 500Lux
- Annual power consumption: 8352×102.6＝856,9000 kWh
- Power bill: RMB 428,400

(Note: Electric ballasts have been installed for energy saving)

(1) Divide the workshop into three functional areas.

- Corridor and product transfer areas: illuminance 150 lux, 284 groups, totally 852 lamps.
- Assembly area: illuminance 350 Lux, 602 groups, totally 1,806 lamps.
- Inspection area: illuminance 500 Lux, 14 groups, totally 42 lamps.

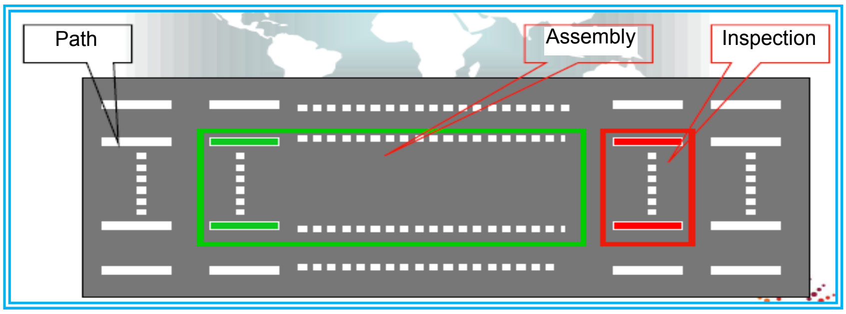


Fig. 3-6 Functional areas in workshop

(2) Redistribute illuminance by adjusting the number of lamps and lamp controls as follows:

- Corridor and product transfer areas: Reduce the number of lamps to 568, eliminating 2 lamps per group.
- Assembly area: Reduce the number of lamps to 602, eliminating 1 lamp per group.
- Inspection area: The number of lamps remains the same. Install reflecting covers to compensate for the decrease of illuminance in peripheral areas.
- A total of 1170 lamps are eliminated..
- Install a switch that controls the lighting of the two lines of lamps close to the windows. These lamps can be switched off during the day.
- Install five switches to control the lighting in product transfer areas. Lighting in this area can be switched off when no one is working there.

(3) Replace lamps with energy-saving lamps and install reflecting covers.

- Install lighting control devices at the lighting level.
- Use LED lamps in inspection areas to protect the eyesight of workers.

»

(4) Provide training to operators on energy efficiency management, including:

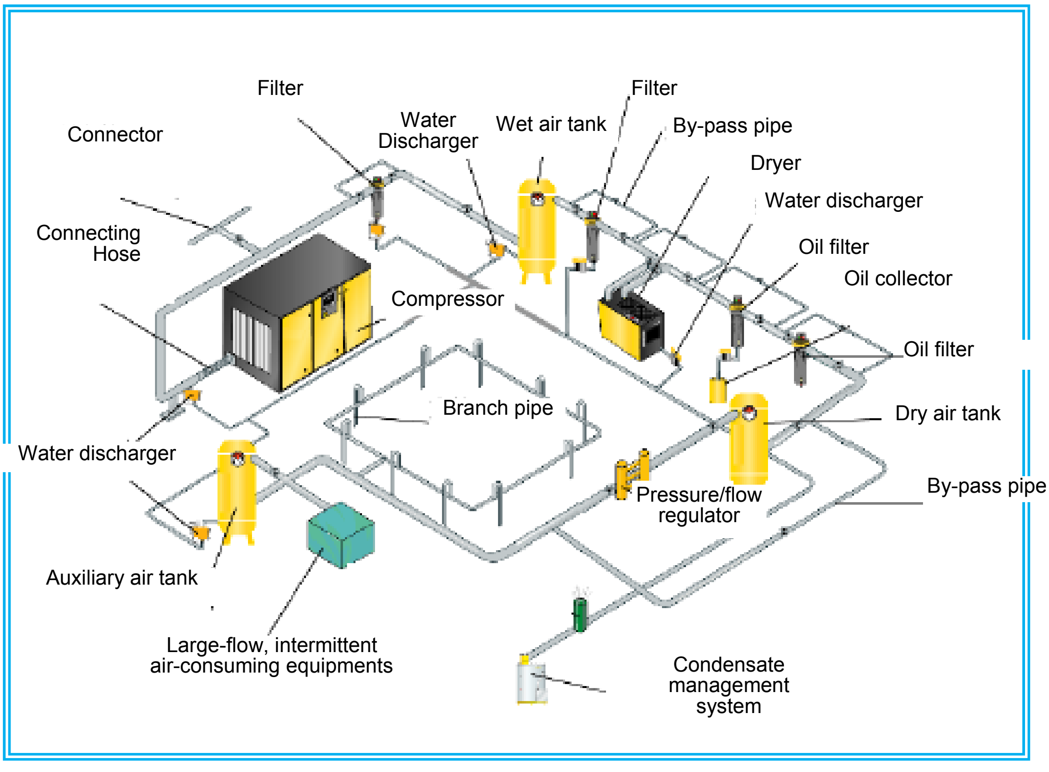
- Energy saving
- Lamp cleaning
- Natural light

3. Compressed Air Systems

3.1 ENERGY-SAVING DIAGNOSIS: COMPRESSED AIR SYSTEMS

Compressed air systems have two parts serving: (1) air supply, and (2) air consumption. Examples of air supply equipment include air compressors, air

Fig. 3-7 Structure of compressed air system



tanks, air dryers, filters, etc, while air consumption equipment comprise pipelines, air storage systems, site filtering devices and air-consuming machines.

As one of the most widely used power sources in industrial production, compressed air is safe, pollution free, easy to control and distribute. However, to generate high-quality compressed air, large amounts of energy are required. In most factories, the power used for producing compressed air is about 10~30 percent of the overall power consumption.

The figure below illustrates the total cost of compressed air over a 10 year period.

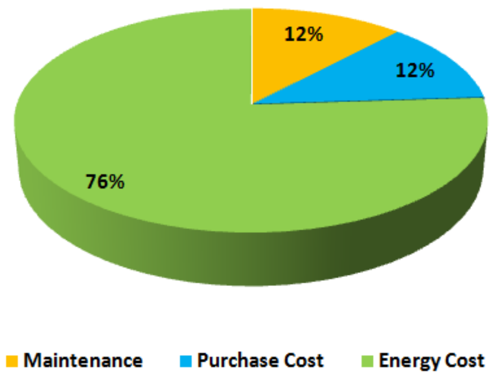


Fig.3-8 Cost of compressed air system

The cost of equipment purchase and maintenance is only a small part of the total cost of a compressed air system, as power costs are usually more than 75percent of the total cost.

The Industrial Assessment Center (IAC) issued a report stating that SMEs in the United States can cut their energy use of compressed air systems by 15 percent, with a two-year payback period.

Given that the efficiency of motor systems in China is 20 percent lower than that of most developed countries; China-based SMEs have the opportunity to reach energy savings of up to 40 percent.

Compressed air is possibly the most expensive form of energy. If a pipeline is thermo-insulated and it is used at the same level of temperature as when the compressed air leaves the compressor outlet, energy can be used efficiently. It is difficult to achieve this, however, because to produce 1kW of power, pneumatic motors require about 5.2kW input of compressor power. In other words, only 19 percent of energy consumed by a compressor is converted into useful power, the remaining 81 percent becomes waste heat.

Note that this calculation is theoretical and does not account for additional losses, including damaged pipelines, a mismatch between the compressor and equipment, system leakage and faulty system controls.

3.2 ENERGY-SAVING MEASURES FOR COMPRESSED AIR SYSTEMS

To reduce the energy consumption of compressed air systems consider:

3.2.1 TEMPERATURE OF INLET AIR

Compressors absorb all impurities in the air, condensing them several fold, thus the quality of the inlet air filter has a large impact on the performance of the compressors. A general rule is "a 4°C increase of inlet air temperature results in one percent more energy consumption," meaning relatively cool air is better for achieving higher compressor performance.

Fig.4-4 Impact of inlet air temperature on power consumption of compressor

Inlet air temperature (°C)	Relative output air (%)	Power saving (%)
10.0	102.0	+1.4
15.5	100.0	Nil
21.1	98.1	-1.3
26.6	96.3	-2.5
32.2	94.1	-4.0
37.7	92.8	-5.0
43.3	91.2	-5.8

Source: The Confederation of Indian Industry (CII)

3.2.2 FILTERS

A compressor should have an intake air filter installed, or the air used should come from a clean, cool location, to minimize maintenance of the compressor. Note that the pressure drop of the filter should be kept to a minimum (by adjusting the filter size) to prevent a throttling effect and a decline in the compressor's performance. In general, efficiency will be reduced by two percent for every 250 mm of water column pressure drop across the filter.

Table 4-5 Impact of filter pressure drop on power consumption

Filter pressure drop (mmWC)	Increase of power consumption (%)
0	0
200	1.6
400	3.2
600	4.7
800	7.0

Commonly seen air filters

PrefilterPartical filter **Mini-filter**

Pre-filters can be used as primary filter for 100% saturated compressed air (or liquid-phase steam). They have the same filtration mechanism as that of other thick-

Particle filters can be used to remove dust in dry air from outside to inside. They are usually used as surface filters.

Mini-filters can move 0.01~0.001 micron particles to the outside. They are suitable for in-depth filtration.

3.2.3 DISTRIBUTION SYSTEM OF COMPRESSORS

Pipe diameter: Air distribution systems supply air into terminal units, thus the system requires the correct pipe size to minimize falling pressure. Excessively small pipes result in resistance to the air flow, which increases energy consumption and pressure fluctuation.

Selecting a pipe size:

» The recommended pipe size should not exceed 6 meters per second to ensure pressure losses are kept to a minimum, and to allow the pipeto maintain a moderate air flow even if more compressors are installed in the future.

» The size of the pipe for air distribution should allow less than 9 m/s of air flow.

» The size of the pipe for terminal units should allow less than 15 m/s of air flow.

Minimize pressure drop: Pressure drop occurs in compressed air systems when pressure moving from the compressor outlet to the terminal unit declines. Any sort of obstruction or roughness in the distribution pipeline will cause resistance to the air flow, but when the air system is well designed, the pressure loss should not exceed 10 percent of the compressor’s outlet pressure.

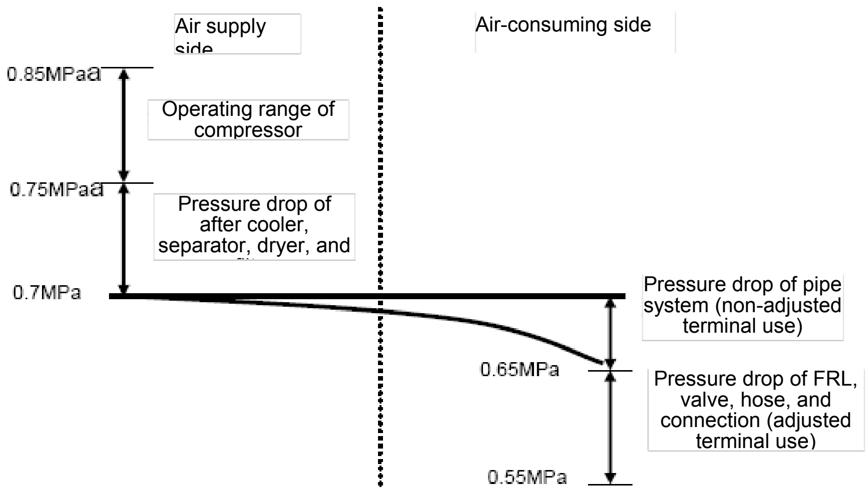
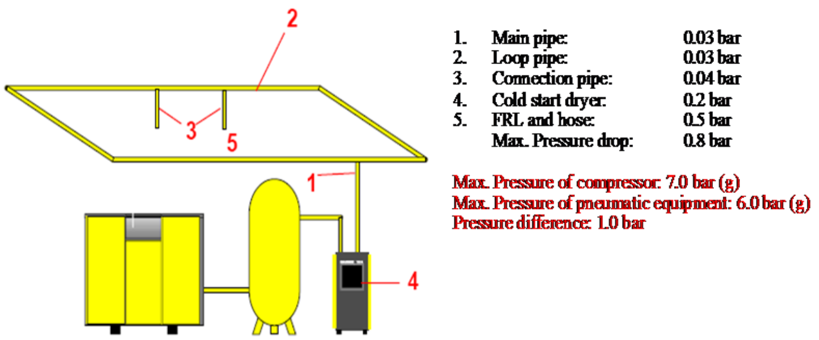


Fig.3-0 typical pressure gradient

Case study of a typical pressure gradient



The normal operating pressure for pneumatic tools is 6 bar (g) (1bar(g)=1kg). Any pressure higher than this will cause a rise in costs.

- Air consumption V = 40 m^3/min at 7 bar(g) 250kW.
- At 8 bar(g), 7% more power (>15kW) is required.

Increase of cost:

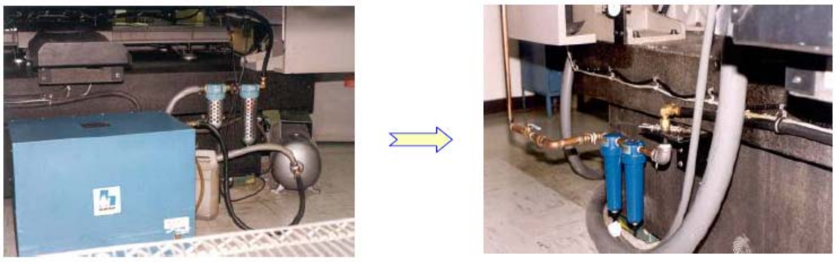
- 15 kW x 0.6RMB/kWh x 8000 h/year = 72,000RMB/year

Pressure drops can be minimized three ways:

» **Select proper equipment.** Select air treatment components, such as after coolers, gas-liquid separators, driers and filters, with the lowest possible pressure drop at specified maximum operating conditions. Or select terminal units, such as pressure regulators, lubricators, hoses, and connections with the best performance characteristics at the lowest pressure differential.

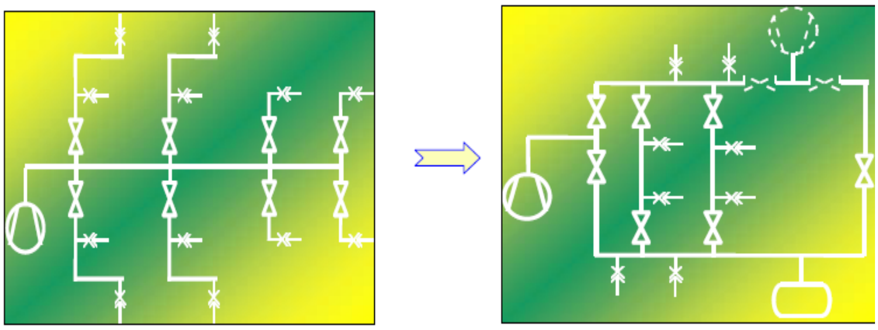
» **Correct system maintenance.** Monitor the pressure drop of each system component and conduct regular maintenance following supplier instructions.

» **Pipe optimization.** Industrial compressed air systems usually experience rapid fluctuations. Even a well-designed pipeline can experience a sudden decrease in pressure after the installation of a new terminal unit. To deal with this problem, raise the compressor discharge pressure, since even a small modification of the air supply pipeline can help reduce the energy consumption of the entire system.



How to Fix a Faulty Compressed Air System

The pictures above show pipelines for a typical compressed air system. This kind of configuration usually results in a 0.14~0.2 MPa pressure loss between the air pipe and the terminal unit. To resolve this issue, reduce the length of the hose and use metal pipes as much as possible.



Changing the pipeline network layout solves the problem of low terminal pressure and improves air efficiency, while reducing input pressure.

3.2.4 STORAGE SYSTEMS

Certain intermittent, high-load air applications in factories may cause air system pressure to experience serious fluctuations. As a result, pressure-sensitive processes cannot don't smoothly and product quality is affected. A solution to this problem is to raise the discharge pressure or capacity of the compressor. But this could lead to an increase in power consumption (a 0.1 MPa increase of discharge pressure results in a seven percent increase of the compressor's power).

Problems of this kind can be solved by installing an air tank. Since high loads usually last for a limited period of time, and there is an interval between loads, this interval can be used to fill the tank, thus satisfying the extra demand for air without increasing the capacity of the compressor.

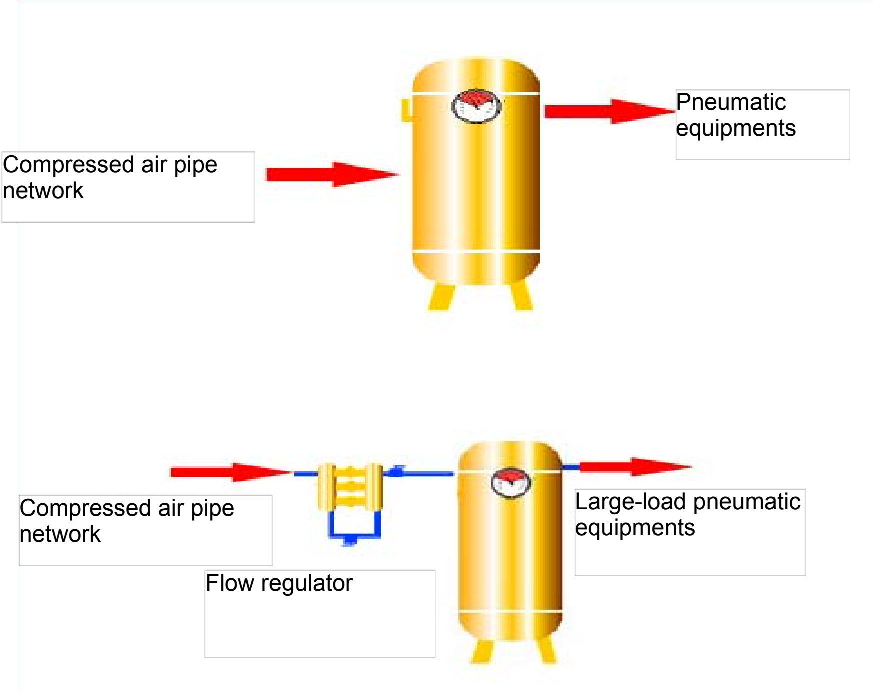


Fig. 3-10 Storage system of compressor

3.2.6 SELECT CONTROL STRATEGY MATCHING WITH SYSTEM LOAD

The purpose of system control is to ensure air supply satisfies air demand. Therefore, a good control strategy is essential for maintaining a high efficiency operation of the air system. An air system usually is made of multiple air compressors. A good strategy is to allow full-load operation of running compressors and stop those that are not running.

3.2.7 AIR LEAKAGE

In an industrial compressed air system, leakage may result in a 20 to 30 percent waste of total air production.

Table 4-6 Leakage loss of compressed air

Hole size	Air consumption at 6 bar(g) m^3/min	Power loss (kW)
1 mm	0.065	0.3
2 mm	0.240	1.7
4 mm	0.980	6.5
6 mm	2.120	12.0

Note: If the power price is RMB 0.6/kWh and annual running time is 8000hours/year, then the leakage loss due to a 4mm hole will be RMB 31,200/year.

Fig. 3-11 Air Leakage Detection

Air leakage cannot be perceived visually and hence needs to be detected using the appropriate methods. The best way to detect air leakage is by using an ultrasonic detector, which can detect the sound of air seepage beyond ordinary human auditory capabilities. A portable air leakage detector is generally equipped with a microphone, an amplifier, a filter, an indicator, as well as an earphone piece. A less complex method of air detection can be conducted by simply using soapy water, which although a very reliable method, can also be time-consuming.

A simple way to calculate leakage:

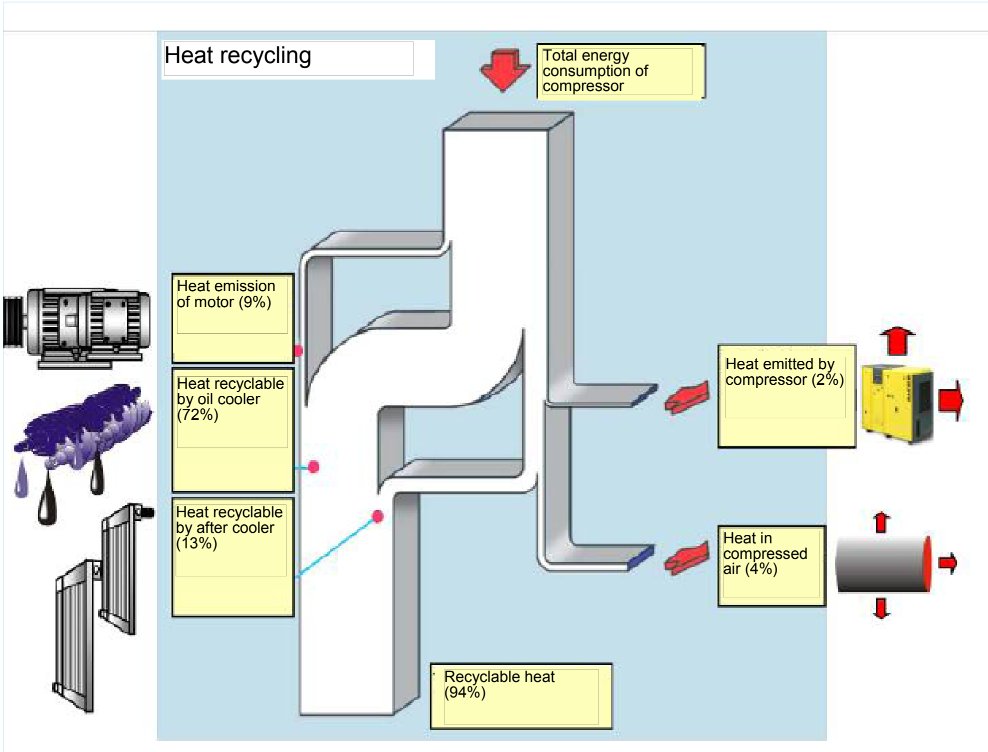
- Switch off pneumatic equipment or do the test when no equipment is in operation
- Run the compressor and check the operating pressure
- Record the time required to complete the cycle of loading and unloading. To obtain precise data, record the time required to run 8 to 10 cycles, and then calculate the total loading time (T) and unloading time (t).
- Use the following formula to calculate the leakage rate. "Q" is the actual air supply (m3/min). Total leakage rate (m3/min.) would be:

$$Q \times T(T+t)$$

3.2.8 HEAT RECYCLING

About 80 to 93 percent of power consumed by an industrial air compressor is converted to heat. In most cases, 50 to 90 percent of such heat can be recycled and used in heating air or water. Heat recycling is possible for both air-cooled and water-cooled compressors. Typical applications of heat recycling is in auxiliary space heating, process heating, water heating, circulating air heating, and water preheating for boilers.

Fig. 3-12 Illustration of heat recycling



Application of recycled heat

Recycled heat from cooled air is suitable for heating spaces. When air passes through after-heaters and lubricant coolers, it absorbs heat from compressed air. This can be used for heating spaces, drying or preheating for boilers. A rule of thumb is that about 5kW energy can be obtained from a $1m^3$/min capacity (full load). The heat can be used to heat air to a temperature that is 16～22°C higher than the cool air inlet temperature. The recycling efficiency is usually 80 to 90 percent.

4. Air-conditioning and Ventilation Systems

4.1 ENERGY DIAGNOSIS: AIR-CONDITIONING AND VENTILATION SYSTEMS

An air-conditioner is a device that can "move" the hot air in a room to the external atmosphere through four phases of heat transfer. Each heat exchange is a process that consumes energy.

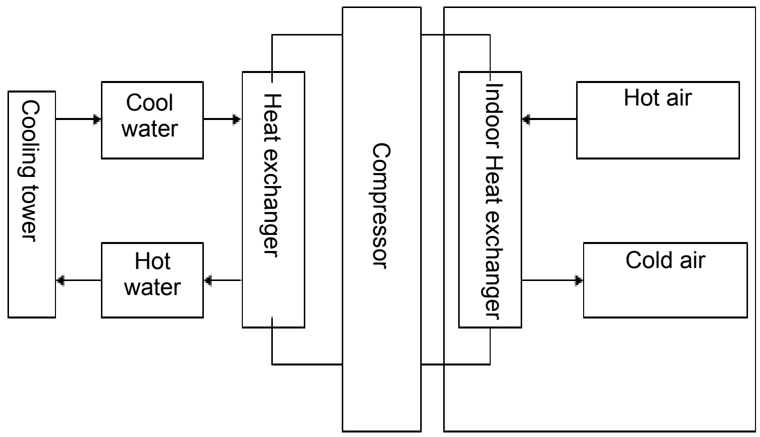


Fig.3-13 Operating principle of central air-conditioning system

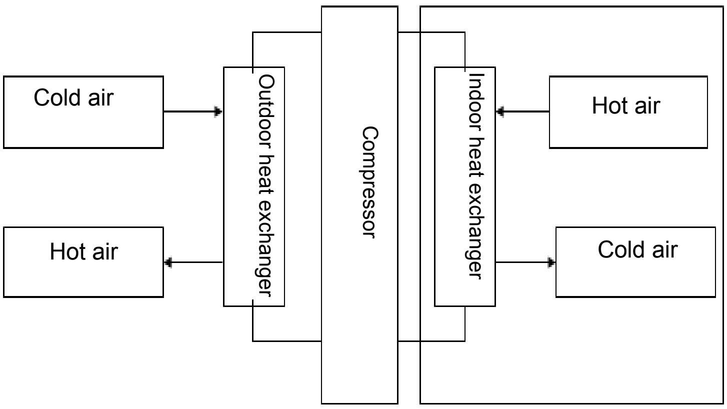


Fig.3-14 Operating principle of split-type air conditioner

Efficiency of air-conditioning system ＝Cooling capacity/Input energy ＝COP

COP is the most important energy performance indicator for air conditioners. It has clearly defined limit values in the national standards. Check the COP before you purchase any air conditioner.

The power consumption of a central air-conditioning system is the sum of the power consumption of the compressor, the chilled water pump, the indoor heat exchanger's fan, the cooling tower's fan, and the cool water pump.

Factors affecting the energy performance of a central air-conditioning system are the efficiencies of the compressor, the two water pumps, the two fans, and the heat exchanger. A decrease in efficiency of any of these components will result in the increased power consumption of the other components.

The power consumption of a split-type air conditioner is the sum of power consumption of compressor, indoor heat exchanger fan, and outdoor heat exchanger fan.

The compressor consumes 75 to 80 percent of the power while the two fans consume 10 percent of the power.

4.2 MEASURES FOR REDUCING POWER CONSUMPTION OF AIR-CONDITIONING AND VENTILATION SYSTEMS

How can we reduce the power consumption of an air-conditioning system?

- Reduce the heat intake (this is equivalent to reducing the cooling demand and is a low-cost solution.)
- Maintain or increase the heat-exchange efficiency (no/low-cost solution.)
- Reduce "cooling loss" (no/low-cost solution)/reduce cooling space.
- System automation (high-cost solution.)

General low-cost solutions:

- Maintain the efficiency of the two heat-exchangers by regularly checking and cleaning the filters.
- Reduce "cooling loss" and insulate the chilled water pipe (the surface temperature should not be five degrees higher than room temperature).
- Reduce heat intake.
  - Do not open windows/doors when the air-conditioner is in operation. If you have to open awindow/door, using curtains in doorways to avoid the loss of cool air.
  - Use energy-saving wall materials and glass or uselow-cost insulation measures such asinstalling shades.
- Do not switch on power-consuming equipment unless necessary.
- For unavoidable indoor heat sources, such as equipment producing large amounts of heat, consider insulation, heat recycling, or the expulsion of heat to the outside.

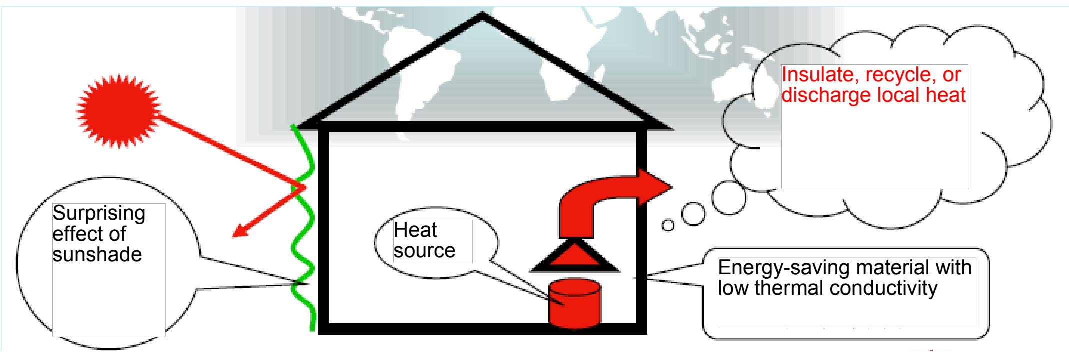


Fig.3-15 Reducing indoor heat source

Many companies have a central air-conditioning system that consumes a lot of power. The following measures can be taken to reduce power consumption.

- Install an appropriate chilled/cooling water pump. Pump parameters need to be decided according to the actual conditions of the system. Excessively high parameters may result in hidden waste.
- Check the efficiency of the cooling tower regularly. Generally, the temperature drop of

a cooling tower is about 5 degrees, and the outlet temperature is one to two degrees higher than the ambient temperature (evaporation rate being 1.5 percent). Maintenance or cleaning work will be necessary if the cooling efficiency is lower than the above-mentioned values.

» Ensure good insulation of chilled water pipe.

» Check the efficiency of the three heat exchanging devices regularly; keep the surface of heat exchanger clean; and clean filters regularly.

» Make sure that there is a switch in each independent room, which can be used to turn off the fan of the heat exchanger.

» A central air-conditioning system is suitable for cooling a relatively large area but not for achieving a reduced temperature in a small space (such as areas that need to be maintained at 22 degrees Celsius or lower). For the low-temperature cooling of a small area, use a cabinet-type air conditioner.

» Set the chilled water outlet temperature at nine degrees Celsius to increase the chiller's energy performance.

"Supply as demanded"

In places where constant temperature is required, install air conditioners with appropriate power that can ensure constant room temperature even in adverse weather (e.g. ambient temperature is 40℃).

In very crowded offices (area per capita less than 2m2), select air conditioners according to the standard method, and install ceiling fans.

In offices that are not crowded, select air conditioners that have a power of about 70% of the standard power and make sure the air outlet face seats.

Energy-saving solutions for split-type air conditioners:

» Select frequency conversion air conditioners with a high-energy performance ratio.Decide the power of the air conditioner according to desired cooling requirements.

» The setup temperature should not be lower than 26 degrees Celsius. If the air outlet faces worker areas directly, the setup temperature can be 28 degrees Celsius.

» Turn off air conditioners 30 minutes before the close of the business day (Never let air conditioners run overnight). Avoid positioning outdoor units in direct sunshine and ensure uninterrupted airflow. Place a protective covering over the unit if it is not to be used for a long time.

4.3 CASE STUDY: SAVING ENERGY AT A FOOD PROCESSING PLANT

The preparation workshop at a food processing plant has five outlets for a central air-conditioning system, one 18kW indoor air conditioner, eight sugar melting pots with a surface temperature higher than 60 degrees Celsius, and one vacuum tank with a surface temperature higher than 80 degrees Celsius. There are many pipes for distribution of hot water and steam. The surface temperature of these pipes is higher than 50 degrees Celsius. The annual power consumption of the air-conditioners is 1,360,000 kWh. The temperature of the workshop is required to be 22 ± 2 degrees Celsius.

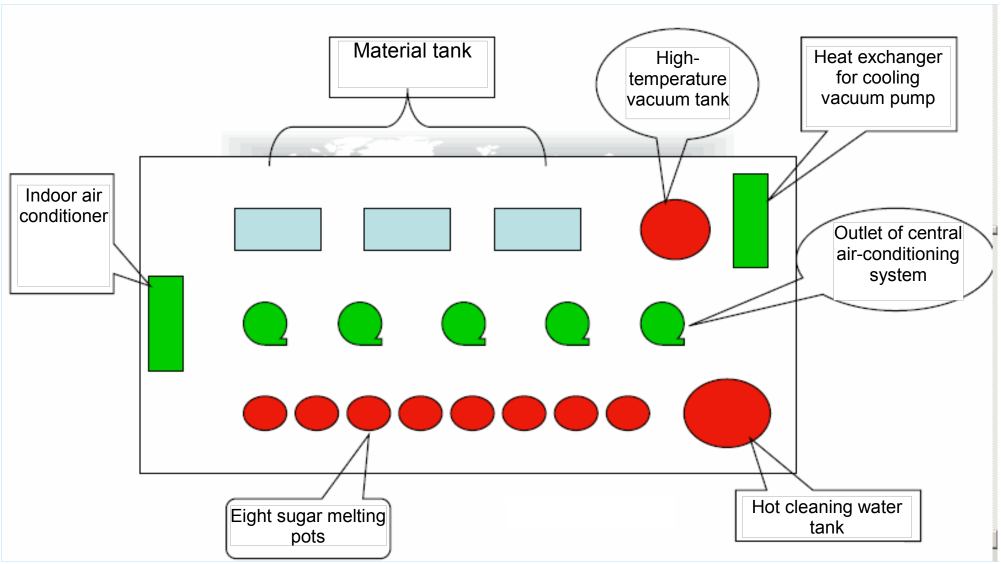


Fig.3-16 Layout of preparation workshop

Analysis of high power consumption:

- The only place in the workshop that needs to be cooled down is the material preparation area.
- Air-conditioning is needed in winter because there are too many heat sources in the workshop.
- The workshop solely relies on an air-conditioning system without considering the use of natural air during the cold season. The power bill in January 2008 was more then RMB 300,000.

Solutions:

- Use partitions to divide the workshop into several areas. Use three of the five outlets of the central air-conditioning system and close the other two. Move indoor air conditioners to other places.

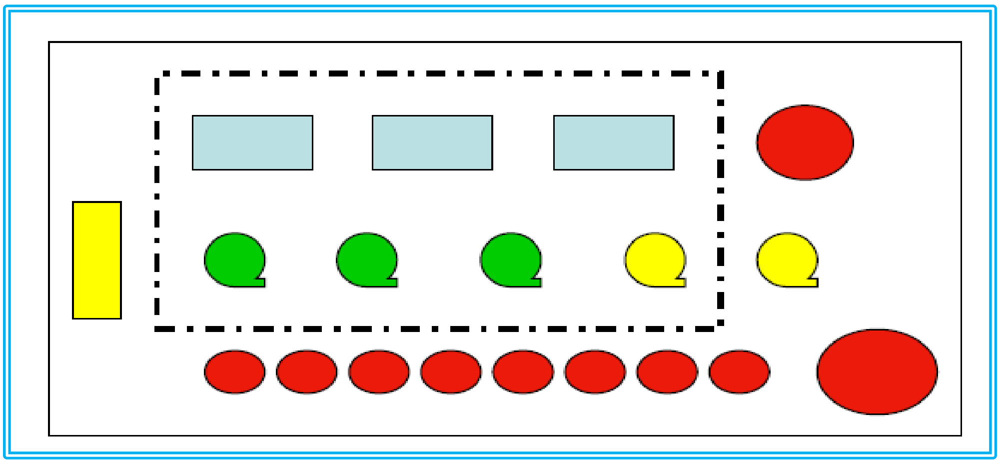


Fig.3-17 New layout of workshop

» Insulate high-temperature containers to reduce steam consumption and to reduce the load on the air-conditioning systems.

» Replace the high-temperature vacuum condensing process with a low-temperature vacuum condenser. This will alsohelp reduce the load onthe air-conditioning system.

» Replace heat provided by steam with the heat generated in the heat pump. Use the cold air from the heat pump to cool down the material preparation area. This can further reduce the load on the air-conditioning system.

The total investment for all energy saving measures was RMB 276,000, while annual power savings were 370,000 kWh.

Fig.3-18 Pictures of the workshop before and after the energy-saving project

5. Injection-Molding Systems

5.1 ENERGY-SAVING DIAGNOSIS

Similar to a syringe, an injection-molding machine has a screw or plunger that can inject plastic fluid into a die cavity. Plastic fluid solidifies in the die cavity and products are formed. Usually a hydraulic transmission machine, an injection-molding machine consists of an injection device, a die opening/clamping device, a hydraulic transmission device, and an electrical control device. Injection and die opening/clamping devices are key components of an injection-molding machine. Electrical control devices ensure that the machine operates correctly according to the process requirements (such as pressure, speed, temperature, time, and position) and specified procedures.

Tests indicate the amount of power consumed by each component in an injection-molding machine is:

- Hydraulic system: 75-80 percent
- Heating unit: 10-15 percent
- Cooling system: 5-10 percent
- Control system: 1-5 percent

A hydraulic system consumes more than 75 percent of the machine's overall power consumption. The hydraulic loss of an injection-molding machine consists of three parts:

- **Overflow loss**: Depending on products and processes, the hydraulic power, flow, and pressure of processes vary. The load of the machine is always changing. Oil pumps are designed to satisfy the largest flow and the motors run at constant speed. When the flow needed is less than the largest flow, the excess oil runs back to the oil tank through an overflow valve. The energy used to provide this part of oil is then wasted.
- **Throttling loss:** This refers to the pressure drop of hydraulic oil when it runs through a throttle valve. Since the throttling area of directional valve is relatively large, most throttling loss occurs at the directional valve. The high-speed circulation of hydraulic oil as well as friction with hydraulic parts leads to high oil temperature, noise, and the reduced life-span of the machine.
- **Design surplus loss:** In most cases, the design capacity of a motor is much higher than actual requirements. This also leads to waste of power.

5.2 ENERGY-SAVING MEASURES FOR INJECTION MOLDING MACHINE

An energy-saving upgrade of an injection-molding machine can be conducted considering the following aspects.

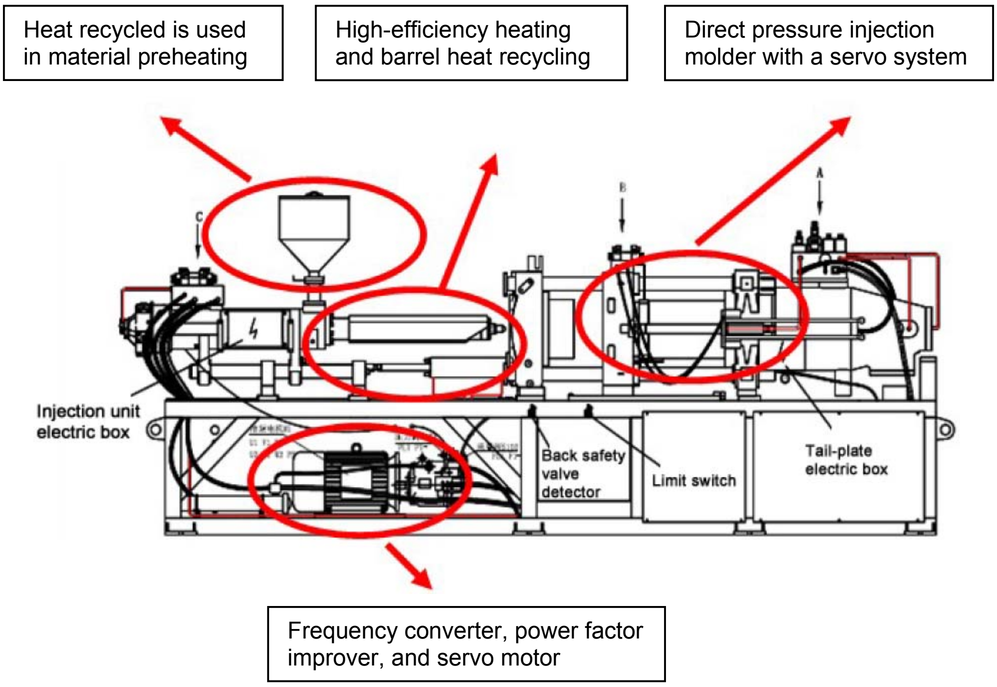


Fig.3-19 Energy-saving opportunities of injection molding machine

5.2.1 INFRARED ENERGY-SAVING HEATER BAND

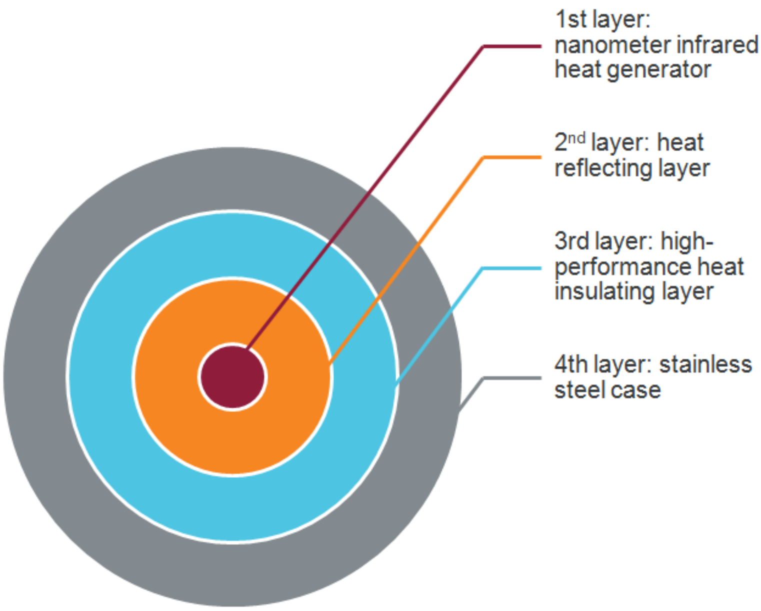


Fig.3-20 Infrared energy-saving heater band

Features:

- Heating speed: Heats up nanometer material to 1000 degrees within 45 seconds and maintain 750 degree temperature for a long period of time.
- Heat conversion efficiency: >99.8 percent.
- Life span: Allows for continuous use for more than 50,000 hours.

» Insulating/one-way heat transfer performance: Maintains less than 80 degree surface temperature.

Result: Power savings of 25 to 50 percent; return on investment period is five months.

Fig.3-21 Before and after upgrading using infrared energy-saving heater band

5.2.2 HEAT RECYCLING

The heat generated by the barrel of the injection-molding machine can be recycled for preheating materials. This can reduce heat loss and power consumption of the material preheater without affecting the operation of the machine. An insulating case is installed to conserve the heat produced by the heater band, and the hot air in the space between the case and the barrel is transferred to the material preheater by a fan. The air is then passed through a filter, which removes the dust in the air, and is transferred back to the space between the case and the barrel, ultimately forming a heat cycle. Due to an increase in thermal efficiency and a reduction of heat emission, the workshop will be cooler with power consumption and dissipation reduced.

High power consumption and heat emissions have long been problems with conventional injection molding machines. Such problems lead to increased production costs and power consumption as well as environment impacts. Heat emission of an injection molding machine is mainly due to the following problems:

(1) Material preheats using resistance wire, which generates heat on both inner and outer surfaces. The heat on the outer surface escapes into air and is wasted.

(2) High surface temperature (200 to 300 °C) of the barrel which makes the workshop very hot. During the summer, the temperature in a workshop can be more than 40 °C. Factories tend to use air conditioners to cool down workshops, but this only leads to secondary waste of energy.

Fig.3-22 Heat recycling equipment for an injection-molding machine

A power meter is installed to measure the power consumption of the barrel, the material hopper, and the injection-molding machine after the installation of a heat-recycling system. The same is done on other machines without this device. The data is used to calculate energy consumption and power costs of the machine before and after the installation of the heat-recycling system, as well as to estimate operating costs and payback periods.

Table 1 Energy saving and economic effects

Heat recycling equipment	Power factor	Injection molding machine		Material preheat barrel		Payback period (year)
		Power consumption (kWh)	Energy saving (%)	Power consumption (kWh)	Energy saving (%)	
Plant A						
Heat recycling equipment installed	0.88	31	1.6	2.3	20.7	2.4
Heat recycling equipment not installed	0.88	30.5		1.69		
Plant B						
Heat recycling equipment installed	0.67	4.93	4.3	0.12	69	4
Heat recycling equipment not installed	1	5.15		0.38		
Plant C						
Heat recycling equipment installed	0.77	1.13	16.3	0.36	37.9	0.4
Heat recycling equipment not installed	0.85	1.35		0.58		

As shown in the table above, plants installed with heat-recycling equipment reduced their power consumption. The decrease in power consumed by the preheat barrel and the injection-molding machine was 20.7 to 69 percent and 1.6 to 16.3 percent, respectively. The payback period was 0.4 to 4 years. Test results show the heat-recycling equipment is effective in reducing power consumption and the costs of the preheat barrel. The test results of the injection molding machines, however, showed the power consumtpion depended on the product and therefore only reflected the results achieved at the operating conditions of the equipment.

5.2.3 DIRECT PRESSURE INJECTION MOLDER WITH SERVO SYSTEM

Conventional injection-molding machines have fixed pressurizing systems, which rely on motor-driven pumps. The speed and pressure needed in each step of injection-molding are different, so are the oil flow requirements. However, the motor rotates at constant speed and provides oil at constant flow. As a result, some of the oil is not utilized and therefore becomes waste. Another waste product is the heat generated by resistance heaters, which is not used up but instead flows back into the workshop. The figure below shows the Lijin PT300Y direct pressure injection molder with servo system used in a factory.

The machine is equipped with a servo motor, which can adjust its output power in real time based on the change in load. The servo system can control the rotating speed of the motor pump according to power demand of the machine, the pressure monitor and the flow change, and therefore reduces its power consumption. In other words, the controller adjusts the rotational speed of motor (and as a result, its output power) according to change of load, at the same time improving the power factor. In addition, the machine has an electromagnetic heating system, which generates large amounts of eddy currents that can produce heat in the metallic material. Since the heat is dissipated by the metallic material, the external heat loss is very low. This can help increase power efficiency.

Compared to a conventional injection-molding machine, the direct pressure injection molder with servo system saves more power, allows more accurate operation, generates less noise, improves product quality and saves operating costs.

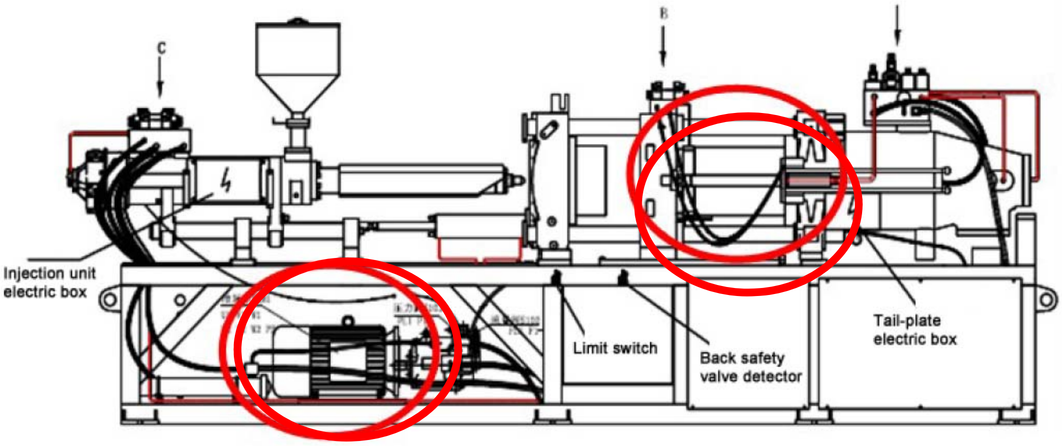


Fig.3-23 Direct pressure injection molder with servo system

Fig.3-24 Conventional injection-molding machine vs. direct pressure injection molder with servo system

To verify the performance of a direct pressure injection molder equipped with a servo system, a company carried out a test using the direct pressure injection molder with servo system (Lijin PT00Y) and the conventional injection molding machine (Baoyuan 320PC and PC-550) , both of which have the same tonnage given the same test conditions. The result is shown below.

Table 2: Result of test on conventional molder and direct pressure injection molder with servo system with the same tonnage (clamping force) in production of TS-728 kitchen basin

Test items	Conventional injection molder	Direct pressure injection molder with servo system	Saving %
Power consumption/unit time (kWh)	14.8	2.7	-81.8%
Production cycle (sec.)	80	75	-6.25%
Pass rate (%)	85	97	+12%
Qualified product (EA/hr.)	35	42	+20%
Workshop temperature (℃)	41	32.5	-20.7%
Maintenance cost (RMB/year)	The die-clamping device needs 1 liter of lubricant every day and one grease lubrication per season.	Do not need daily lubrication, but only one grease lubrication per season.	- RMB 5600

Table 3 Direct pressure injection molder with servo system vs. injection molding machine with the same opening stroke (PT300Y:910mm and PC-550:850mm)

(in production of TS-806 water tank)

Test items	Conventional injection molder	Direct pressure injection molder with servo system	Saving %
Power consumption/unit time (kWh)	23.5	3.2	-86.4%
Production cycle (sec.)	92	70	-23.9%
Pass rate (%)	83	96	+13%
Qualified product (EA/hr.)	36	45	+20%
Workshop temperature (℃)	40	31.5	-21.3%
Maintenance cost (RMB/year)	The die-clamping device needs 1 liter of lubricant every day and one grease lubrication per season.	Do not need daily lubrication, but only one grease lubrication per season.	- RMB 5600

As shown in the table above, a direct pressure injection molder with servo system has the following advantages:

» **Significant energy-saving effect:** The servo motor and measuring pump start to run only in specific processes. For an interval of about 45 seconds, they are stopped and consume no power at all.

» **Low maintenance cost**: Daily lubrication is not necessary, which means savings of two barrels (180L) of lubricant.

» **High production output and short production time**: The computer-based control system is highly accurate, flexible, and reliable.

» **Less impact to ambient temperature in workplace**: With relatively low operating temperatures and good insulation of electromagnetic heating systems, the machine emits less heat.

Financial analysis

A direct pressure injection molder with a servo system is usually used in the manufacturing of products that require long opening strokes. In the production of the TS-806 water tank, the molder saves 20.3 kW more than a conventional molding machine with the same opening stroke. In the production of the TS-728 kitchen basin, the molder saved 12.1 kW more power than a conventional molding machine with the same clamping force. A conservative estimate is that the molder saves about 15kW more power than conventional molding machines.

Table 4 Financial analysis

Running days (days/year)	Running hours (hours/day)	Power price (RMB/kWh)	Production cost (RMB/day)	Lubricant saving (barrel/year)	Lubricant price (RMB/barrel)
300	20	1	1350	2	2800

As shown in the table above, the annual power cost saving is: 15 ×300 ×20 ×1 = 90,000 RMB. A short production cycle also contributes to reduced production cost. The standard production cost of 300T molder is RMB 1,350/day. Considering an increase of production by 20 percent, a conservative estimate is 15 percent reduction of the operating time.

» Annual cost saving: 1350 ×15% ×300 = RMB 60,750

» Annual maintenance cost savings: 2,800 ×2 = RMB 5,600

» Annual expense savings: 90,000 + 60,750 + 5,600 = RMB 156,350

» Since the investment is RMB 408,000, the payback period will be: 408,000 / 156,350 =2.6 years

5.2.4 FREQUENCY CONVERSION UPGRADING OF INJECTION MOLDING MACHINE

By installing an energy-saving inverter, it is possible to control the motor speed by adjusting power frequency,therefore reducing the speed to the minimum level where the motor produces reactive power. The energy efficiency can be increased by 10 to 20 percent.

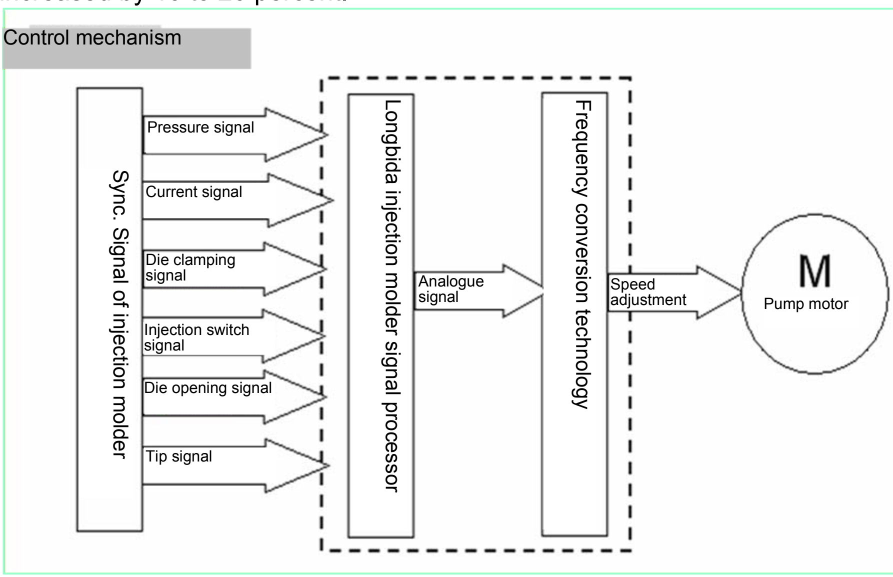


Fig.3-25 Frequency conversion upgrading of injection molding machine