Hydraulic Ram Handbook

A guide for policy makers, technicians and users based on experiences made in the P.R. of China

BORDA

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Preamble

Nothing in the world is softer and yielding than water,
Yet, in vanquishing the solid and rigid,
it has no equal,
while nothing can alter it.

That the week overcomes the strong
and the supple; the stiff,
is something that everybody knows
but none would maintain himself.

Lao Tse

'...Therefore, the gentle and soft is that of a higher quality because it is the lively, the flexible – such as water - and the origin of all that lives. Having mentioned water as an incarnation of the soft, the Yin, is capable of conquering the hardest -the rock.'

Karl Heinz – Pohl

The preliminary remarks to this technical handbook, based substantially on mutual project experiences of the Chinese partners and BORDA, shall give an intellectual impulse to the theme 'water economy', explain the integrated work concept of BORDA with its cooperation partners and show that environmental technologies are essentially an elemental part of a sustainable social development.

The most important and decisive conditional natural development towards the beginning of life on our planet, was probably the photosynthesis about 2 billion years (2 x 10^9 years) ago.

- Less than 50,000 years ago, humans learned to use potential energy regenerated from biomass.

- The next important step leading to a steady and continuous (sustainable) development was the capability of curing diseases and decreasing mortality rates

- During the last 150 years, population on earth increased from about one billion to more than six billions. Everyday, the world's population is increasing by approx. 200,000 people. This means that a city in the size of Hangzhou in China or Munich in Germany, ought to be built every week, an unimaginable thought if one would only consider the necessary additional infrastructure. Since this is not possible, mega cities would still grow. This phenomenon of vigorous growth is not only marked by the fast increase of global population, but also by consumption of energy and natural resources, as well as by a fast increase in knowledge and an expanding mobility depicted through global communication and transport system.

The vast majority of people have little, or no, share in this rapid development of recent history, while others can utilise the possibilities and chances. The gap between poor and rich ceaselessly widens.

Mr. McNamara, former president of the World Bank, described poverty as a living condition, which is so much characterised by malnutrition, illiteracy, disease, infant mortality, and low life expectancy that it ranges below all reasonable definitions of human dignity.

Modern and appropriate technologies, their transfers and knowledge, but also appropriate politics, could offer chances and instruments to slowly close the gap between poor and rich.

The founder of ITDG –International Technology Development Group –, Ernst Friedrich Schumacher[1] , was able to initiate a new development concept 'Small is beautiful'. His book was criticised by many.
F. Schumacher wanted more than just to make a rhetoric contribution to the solution of poverty in the south conducted with common methods. He was searching for new possibilities and conceptions and was able to support many small projects worldwide aiming at development of small and middle enterprises through appropriate technologies and self-help.

[1] A world-famous nongovernmental organisation based in London, which in the sixties made development, transfers and dissemination of appropriate technologies its objective

There were many people who contested his idea, be it out of a misinterpreted 'techno-hostility' or because of an outdated ideological way of thinking. But there were also many organisations and initiatives which further developed his views technically and scientifically. One of these

Poverty is one of the worst causes for pollution. Waste problems brought by modernisation should be addressed

organisations is BORDA in Bremen with its integrated approach towards improvement of living conditions through use of technology in connection with social programmes. These are for instance, dissemination of the Hydraulic Ram, the biogas technology or the decentralised wastewater treatment system DEWATS when integrated with housing programmes, vocational training of marginalized young people, small credit schemes, public health services and environmental protection and restoration programmes. Rapid national and global developments confront BORDA's team and its counterparts with the need of integrating technical components to implement socio-oriented programmes in the 'South' but also in 'western' countries .

The rapid industrialisation of many developing countries plays an particularly important role. Industrialisation though fosters economic progress, it creates devastating to catastrophic ecological circumstances. Industrial wastewaters are being discharged without treatment into water sources contaminating waters valuable for agriculture, cultivation and animal production, as well as for a potable water supply of human settlements. Paper mills would serve here best as an example due to their possibly decentralised locations in underdeveloped regions. This industry generates important and additional income, but simultaneously causes awful damage to the environment, especially through its aggressive sewage, known as 'black-liquor'.

Another big and often insufficiently contemplated problem is ‘waste production’ and its demanded ecological disposal. With a growing economy, industrial waste is produced in potentially large quantities. Like wastewater, it represents a continuously growing threat to environment and health. Nature, here rivers, become uncontrolled waste depots, very often endured or even ignored by local governments due to the urgently needed revenues.

But through a managed waste separation and recycling or an appropriate processing, waste could also be utilised economically as valuable raw material or for generation of commercial energy.

The complex problems of both, the supply to- and the disposal from global industrialisation need to be treated in an ecologically-sensible manner and be managed in a way that people in the regions concerned can live free of human-precipitated threats.

Especially during the last decades of the 20th century, it was established that a healthy and a peaceful society can not exist as long as the extreme poverty and environmental damage prevail in the world. Economic development should not come to a stop, but it should consider the needs of life and nature, beyond a national level, in its strive towards a living environment worthy of living for the coming generations. Philippe Roch of Swiss Department of the Environment remarked on the UNCED:

‘The Conference of the United Nations for Environment and Development - UNCED -, which took place in Rio de Janeiro in June 1992, was an event of a very special kind. After all, it brought together heads of States and government officials from all over the world with delegates from UN organisations and representatives of international organisations and nongovernmental organisations, NGOs, to the conference table.

The conference made distinctly clear that environment, economic and social development can not be considered anymore as completely separated fields. The declaration of Rio contains principle rules to which States have to orientate their future decisions and politics, and, at the same time, take into account the repercussions on socio-economic development.

The Agenda 21, an extensive work programme for the 21st century, is a plan for a worldwide partnership, which aims at accommodating the twofold challenge of a high environmental quality and a sound economy for all people on earth’.

Particularly water economy should nowadays be viewed in context of human needs, industrial development and conservation of resources and environment. It should be realised - and acted upon - that the potable water distribution on earth is no more equable. A responsible partaking of all social categories, as stakeholders and protectors of the environment, is the only guarantee of a continuous supply with healthy and pure water. This can be secured through socially just and ecological national and international politics.

It is left for us, for the new generation, to decide the future of our planet. We must learn how to deal with it. - The main conceptional issue of the Agenda 21

1 Socio-Political Background

1.1 Prospects of water economics and its social implications in light of increased industrialisation and modernisation

1.1.1 Long-term utilisation of limited potable water resources in light of the growing world population and increased water consumption in agriculture and industry

In most industrial countries, people take for granted that the desired quantity, or even more, of good, pure and healthy drinking water pours out of the tap, when they turn it on. We even seldom realise the wonderful natural cycle of water lying behind this reality .

That with the help of solar heat, this life preserving fresh water is condensed from the salty sea, and that the wind carries the water-bearing clouds over the land until they fall down again in the form of rain seeping into the ground and returning through wells as fresh water to our taps.

Only very few people are really concerned about this life-sustaining element ‘water’. All over the world, people go on reducing the limited and ever decreasing quantity of water. Agriculture is claiming more water to feed the growing world population, industries to put up its productivity.

Water actually is inexhaustible as it continuously regenerates itself. Consumers discharge their ‘used’ water, which is not simply polluted; but partly chemically contaminated or even poisoned. In the age of industrialisation; our age, environmental sins against water are so tremendous that, in many cases, they are no more redeemable. A good half of the most prevalent diseases in the world are caused by polluted water. Every year, about 25 million people die because of this. 60% of them are children. Diarrhoea is the most widespread fatal disease in this context. These are environmental crimes, which we, or at the latest, our descendants will have to dearly pay for.

The ‘acid rain’ shall be mentioned here exemplary for environmental crimes. Acid rain is caused by exhaust fumes, especially by emission of sulphur and nitrogen oxides, which in the course of the natural cycle of water combine with fresh water in the atmosphere and afterwards, across-borders, destroy forests and turn rivers and lakes to dead waters. The climate of Scandinavia in North Europe, which is for example determined by west winds, presently suffers an unsolvable ecological problem due to immense quantities of exhaust fumes from other countries. Similar situations are known from the United States of America and from Canada, where the problems are far more bigger and have magnified size.

And yet we all learned at school that especially the forest as a reservoir – resembling a sponge - is indispensable for provision of water. Many people consider the forest a source for needed timber. In addition to that, for much people, especially in developing countries, the forest is the most important source of energy. However, the users of this raw material, have not just begun their dangerous exploitation of this source. We all know the news from the media regarding the villainous abuse of tropic rain forests. But critical voices were also not born only recently. The Roman author Lucrez, for example, wrote more than 2000 years: ‘Day by day, the forests were forced to retreat to the mountains in order to give space for building-land at the bottom.’

Water is inexhaustible, nevertheless it is constantly decreasing. It was not a long time ago that the Egyptian Secretary of State for foreign affairs said:

‘The next war in our region will be waged for the water of the Nile and not for politics.’

The world knew eco-refugees at an earlier stage. One thinks for example of the Mongolian town Fatepur Sikri near the North Indian city of Agra, which had to be abandoned by its inhabitants earlier due to the lack of water. In East Africa, whole regions had to be deserted because there is no water and no rain anymore. The natural water cycle guarantees a certain quantity of water in a specific area. This means that the stock of water on earth decreases in proportion to the increase of population. Today, fresh water supply globally is round one third less than in 1970 because the world population has increased by 1.8 billion people. 26 countries on earth with approximately 230 million inhabitants suffer already today water shortage. Further countries in Africa, Asia and Europe will shortly follow.

In some countries, people tried to defer fresh water shortage for a short time by exploiting underground fossil water reserves. The so-called archaic waters are possibly many thousand years old and can regenerate, only to a small extend, through rain waters. These water reservoirs are being exhausted just like oil springs. They represent a 'deceiving' temporary water reservoir and only give illusive security as the following example from Texas / South Dakota proves.

Here are four impressive examples which demonstrate the importance of a long-term water economy:

The 'Green Revolution' started in the industrial countries during the forties of the last century with the aim of increasing agricultural productivity and to eliminate hunger. In Texas and South Dakota, the large underground water reservoir in the high planes was tapped. 30% of the total groundwater used for irrigation in the USA came from this source. - In 1990, 24% - approx. 164 billion m³ - of the estimated existing water quantity had already been exploited. Pumping cost for irrigation constantly increased and became more and more unprofitable, so that between 1974 and 1989 irrigated areas in Texas declined from 2,4 million to 1.6 million hectares.

Sandra Postel from World Watch reports on a further problem which will face mankind in the near future:

About 22% of the world population live in the People's Republic of China. However, they have at their disposal only 8% of the world fresh water resources. As such, problems and predicaments are predetermined. According to Sandra Postel, China's dilemma is visible especially in and around Beijing and in large parts of the North Chinese lowland - a huge, flat and fertile farmland where a quarter of the Chinese grain production is cultivated. Due to the enormous fresh water demand of the mega city Beijing, the groundwater level is annually sinking for more than one metre. Many of the underground springs have already run dry, the lack of water in this region is obvious.

The former Soviet Union irrigated cotton plantations round the Baikal sea. The economic results were favourable. The ecological aftermath of this ruinous exploitation is no more reparable today. A nightmare became true here. Today big ships are lying in a sort of a desert -on dry sand- formerly being the ground of the Baikal sea of which the surface awfully declined. Fishermen at the shores of the lake had to migrate to other regions, and a *mechanised irrigated agriculture existed there for a short time, but had to give way to dry agriculture.*

A last example shall be given figuratively and abstract: 75% of the Saudi Arabian population are supplied with fossil underground water today.

These examples should not create disparity, although we know that they will entail great social and material changes for many people in the near future. They are given here in order to encourage a cross-border cooperation of ecologists, engineers, social scientists and politicians towards an environmentally sound and socially balanced water economy through use of appropriate technologies. After all, a sustainable provision of fresh water from renewable water sources is concerned .

For a long time, irrigation agriculture was regarded as the only promising alternative in development cooperation as far as food security in the South was concerned. This optimism has vanished. A result of the negative practice is that irrigation is being gradually superseded by bigger measures supply food donations.

The conclusion surely is consequential for many large-scale projects if we bear in mind, for example, that the former Soviet Union tried to change the flow of big rivers like the Ob and the Jenessei, so they would carry waters to the south instead of pouring in the Arctic Ocean. Let’s hope that ecological aspects will prevent such huge projects, with there altering affect on nature, from being realised.

In exchange for that, apart from the modest but successful attempts of some civil society organisations, there is nobody to lobby for small farming enterprises. At this point, the big, structure-changing governmental measures should be addressed.

1.1.2 The potential of the hydraulic ram, a ‘socio-technical’ appropriate irrigation technology

The question arises if we can afford to neglect the field of irrigated farming, which presently comprises 18% of the world’s cultivated farmland and produces 35% of the available grain. Contrary to this, there are 45 million hectares of the most fertile and irrigable farmland which are not, or insufficiently, utilized at present because technical irrigation plants are dilapidated, necessary energy is not available, or farmland is over salted due to inefficient irrigation.

Already years ago, the GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit) inferred that we cannot afford to exclude this potential. The potential of these surfaces, (when irrigated) is that they can deliver sufficient food for round 750 million people and, supplementary, about 50 million small farmers can earn livelihood. With comparatively small investment in rehabilitation, considerable production reserves could be released provided that we learn to operate these irrigation schemes efficiently. But, it is the concept of irrigation that is decisive to its utility. Poor irrigation systems were causes of salinity and decreasing loss of soil fertility.

Consequently, Irrigation schemes, need to be considered from a different point of view. One alternative is an intensive small farmers’ food production on irrigated areas, which is embedded into a socio-technical structure. That would necessarily means:

- to consider agriculture within a framework of environmental and resources conservation
- domestic water supply systems to be consider as part of a small structured village supply systems
- integration of appropriate technologies when, for example, wastewater from industrial food processing be treated and re-utilized for irrigation purposes.
- Of special importance are ways to involve village inhabitants in the planning of their village development and to consider their social demands, which is an especially important aspect.

Use of hydro-energy allows utilisation of agricultural lands through irrigated farming in dry areas which -would be otherwise infeasible to irrigate through conventional methods i.e. electricity and Diesel oil. Because of their independence from the need for energy, they would reach areas that would have been otherwise beyond reach.

The Peoples' Republic of China largely succeeded in eliminating malnutrition. This is a great achievement for a country where a fifth of the worlds' population live. Chinese people not only produce enormous food quantities but also guarantee its fair distribution among all inhabitants - which is not less important. The Peoples' Republic of China is furthermore an unprecedented example for ecological agriculture characterised by a persisting endeavour of a zero-waste-approach. Its closed resource systems are practising an extensive recycling of crop residues and by-products.

For millennia, China has been constructing irrigation systems which secure rice cultivation in many parts of the country. In this country, agricultural engineering is not only limited to operating mechanised schemes. As a result, the land is cultivated profitably by millions of farmers. Small-scale farming permits mixed cultivation with its favourable effects on agricultural productivity, if we think for example of high-nitrogenous soy root tubers at the edges of the rice fields. This is a favourable inception to develop other applicable concepts for irrigation management, where technology is the means to improve the living situation of people.

The problem has to be solved in its complexity, that means integration of:

- conservation of the environment and resources,
- application of profitable, but as well ecologically sound technologies,
- socially-balanced politics for the realisation of the concept.

This socio-technical approach to rural development offers the chance to urge a development in rural regions which is simultaneously environmentally-saving. Application of appropriate technologies like the Hydraulic Ram limits the quantity of water used. They allow a restrained utilization of water resources. They take the necessary energy from the water itself, feeded by the already available 'production-input': Water. They do not need expensive outside energy, e.g. electricity or combustion fuel like Diesel oil, which additionally needs an exorbitant transport structure.

In order to use this production-input 'water' in a wise and efficient way, a study should be conducted on environmental compatibility, which examines whether application and use of appropriate technologies is the better alternative for a technical scheme. This step should precede planning and construction of new small-farming irrigation systems.

Only an economic and efficient handling of fresh water, which is available world-wide only in very small quantities at various locations, allows a sustainable and life-improving socio-economic development.

In this handbook, the application, use and dissemination of the Hydraulic Ram shall be treated. The Hydraulic Ram, also called ‘water hammer’, for lifting of surface water is a simple technology in its use and therefore, it is applicable without profound previous knowledge. Its installation, however, requires a basic engineering knowledge. Its use in agriculture and for supply of drinking water requires extensive knowledge in these fields. Because of its simplicity, this product is not of much interest for modern engineering works. The product is made with a relatively low input of high qualified work, compared to the relatively large quantity of material used. Only two parts of this device are in motion, the rest is static.

The challenge BORDA and its Chinese partners faced, was to attain the aim of achieving a rural sustainable development, through a mobilisation of appropriate technology when integrated with and acting as part of a socially oriented programme.

This challenge would continue to presume absolute priority because of the rapid industrialisation in developing countries. The latter plays an important role providing a possibly rapid economic progress, but on the other side, disadvantages to catastrophic ecological conditions.

The authors of this book hope to have contributed to environmental conservation and resource protection, by publishing and illustrating this 200 years old appropriate technology; the Hydraulic Ram, a technology which promotes a responsible development within a framework of a shared sociable habitation of the rural areas being free of the stigma of a technology for the poor and the underprivileged.

1.1.3 Ecology of water, water economics in relation to pollution

1.1.3.1 Natural water cycle

Water is the natural source of life. About 3/5 of the earth, our ‘blue planet’, is covered with water – with the oceans and seas; 2/5 are landmasses. So, there is water in abundance, but only little of it, the fresh water, is accessible and usable for Humans. Water regenerates through the cycle of evaporation and rainfall. The rain forests, for instance those at the Amazon in Latin America or at the Congo, are of decisive importance for the fresh water balance. For this reason, human interference in these great ecological systems is very problematic.

Streams and rivers represent only 0.000003% of all water on earth, but do supply 80% of the drinking water needed by living creatures. This makes clear how careful people actually should be with the fresh water resources. However, only few people are concerned about the element ‘water’.

Water is the basis for life; nevertheless it is treated apathetically. Industry and agriculture are consuming increasingly more water. Wastewater, garbage, rubbish and carcass are carelessly disposed off and thrown into the waters. Only a few metres away, the same water is acquired again for consumption. The increasing need of water and the insufficient treatment of wastewaters - up to the completely absence of treatment - are leading to ecological damages, the dimension of which only coming generations will fully grasp.

Acid rain as an after-effect of the emission of sulphur dioxides and nitrogen oxides and as well, the transformation into steppes and the formation of deserts due to serious mistakes in water management at the planting of mono-cultures, are only 2 examples for the negative influence of human interference on the sensitive water cycle. But also poverty must be mentioned as a cause for environmental damage in the countries of the South. Many people there have no alternative than to further destroy the already endangered environment and, with this, their own life basis, in order to satisfy their basic needs -at least partially. Examples for that are firewood as primary energy, cultivation by burning off, and overgrazing of arid areas.

1.1.3.2 Drinking water

10 litres of water per person/day was the aim of the international water decade of the United Nations from 1980 to 1990. This aim has not been achieved. On the contrary – the water shortage has aggravated. During the last 20 years, water reserves world-wide dropped to the half. For 1.2 billion people, there is still no access to pure, hygienically safe water. This figure has increased with the world-wide growing industrialisation, mostly in those countries giving priority to industrialisation. According to investigations of the UN, every eight seconds a child dies due to water shortage or contaminated drinking water. For long, 'water has become a political resource' the SPIEGEL magazine wrote in May, 2000.

When aiming to achieve an integrated development in the rural areas, fresh water supply as drinking water and water for irrigation becomes a challenging task mainly in regions with insufficient technical infrastructure. Water lifting usually depends on the frequency of energy supply. In many regions, however, there is at present and in the near future no chance to generate the required energy by conventional power plants. It is a vicious circle: lack of energy leads to shortcomings in the process of development, which in return leads to hunger and socio-economic problems.

Water sources are one of the greatest victims of pollution

One of the best alternatives to overcome this severe problem is the utilisation of renewable energy. Since many years, an international working team, which consists of German and Chinese experts and also technicians and engineers from other counties, defined an appropriate technology, the Hydraulic Ram, as being the ideal choice to supply rural areas of the mountainous and semi-mountainous regions with water. It lifts surface water from rivers, stream and perennials to villages which lay over 100 metres above the water source. The hydraulic ram only uses hydraulic energy for water lifting, it requires no conventional energy.

1.1.3.3 Climate

The climate of our earth is mainly influenced by its spherical shape. Near the equator, warming is at its highest, and is constantly decreasing in direction poles. The warming of landmasses and oceans leads to winds and rainfalls. In connection with the rotation of the earth, they create sea currents which carry big quantities of cold water, for example, the Labrador Stream, or warm water like the Gulf Stream, pouring into oceans of contrary-tempered waters and in this way essentially influence the climate.

Through overproduction of nitrogen oxides or excessive deforestation, people are exerting a negative influence on our climate. For this reason, border-crossing, global politics are needed. The frequent occurrence of storms, droughts and heavy precipitations in the form of rain or snow are possible indications for a slow change of climate, the extend of which we are not yet able to realise.

1.1.3.4 Soil erosion

Soil erosion is one of the worst and gravest environmental problems on earth. Each year the enormous quantity of about $35 \times 10^6 m^3$ (35 million m^3) of soil are carried away by water and wind to be washed into the sea, a great part of it is valuable fertile soil indispensable for plant cultivation. There is no way to replace this soil.

Soil erosion is caused by winds and rainfalls. Human interference in nature intensifies this process. Deforestation is one of the gravest causes, but also unprofessional agriculture at steep land without terraces, and excessive overgrazing are important causes for soil erosion.

Terrassing is the most common way of protection to prevent agricultural fields from erosion

1.1.3.5 *Solid waste*

Living organisms consume energy and produce residues, waste and garbage in this process, which can be naturally decomposed and returned back to the natural life cycle . For example humus, the basis for fertile soil, are developed in this way. In the deciduous forests in the mild climate zones, the annual rate of falling leaves creates only about 10 mm of humus within 30 years.

The human race is consuming a multitude of substances, which cannot - or only in a very long span of time - be decomposed. With the production and utilisation of these materials an enormous quantity of energy is consumed. It is obvious that these quantities of about one billion tons of waste could be a rich source of raw materials. In many countries, steel, copper, aluminium and lead are reclaimed through recycling. China, for instance, recovers a great part of its steel from scrap metal. Waste paper is another important raw material. Not only that great deal of it is needed, but that the natural raw material for it, mainly wood, is biomass. Every day, large wooded areas are deforested for paper production.

Waste must be understood as a resource and not be kept on rubbish tips

In many places, waste and garbage are indifferently ‘disposed’ in nature with complete apathy , chiefly into running waters. Sarcastically spoken, added to Wastewater, this is another ‘great’ contribution to perpetual reduction of the already short offer of potable water.

Waste must and can be understood as a resource. Raw materials can be recovered and new materials developed, jobs created and the environment can be sustainably improved. Positively seen, waste can make a contribution in increasing the gross national product. It must not be kept on rubbish tips.

F. Schumacher’s ITDG, for example, developed a concept for an environmentally just recycling of discarded automobiles.

Together with its cooperation partners, BORDA founded the Institute for Energy Efficiency and Environmental Technology; EEET, in order to transfer, disseminate and if necessary to design environmental technologies. This is an appeal and an example to be followed for the industry to share in decreasing waste and minimise environmental destruction.

1.1.3.6 Treatment and draining of wastewater

As mentioned before, water, the source of life, is killing about 25 million people every year - mainly children -, because it is polluted, depleted with urban and industrial toxic substances released into nature without sufficient cleaning. Lack of knowledge, ignorance and greed are the substantial reasons. Governments are reacting much too slow to this serious situation. They are sparing industries as potential taxpayers in spite of a very tight national budget. Added to this, there is only slow realisation of existing decrees for the conservation of the environment.

For a socially sound water management, e.g. healthy water for living and for agriculture, a consequent regulation of wastewater treatment is indispensable, especially against the background of a growing world population and increasing industrialisation.

Water is a limited resource. The only guarantee for a sufficient supply is a consequent regulation of wastewater treatment and a rational utilization.

1.2 Socio-cultural factors and their impact on a sustainable utilisation of water

1.2.1 Role of women

The special involvement of women into a sustainable, environmentally sound development is of essential importance. Especially in developing countries, women carry out a considerable part of agricultural labour and have a great deal of concealed duties. Acquiring drinking water, which needs to be brought over long distances, is usually a part of their tasks. They are largely responsible for the household and, in this way, also for hygiene and health.

Fresh water is the most essential basic need of life. In many countries, it is women's job in the families to collect fresh water. This gender specification of roles here hinders development in the sense that it forms a hindrance for women to play an active role in the society because of labour-intensive daily work (here, dragging water with buckets along the mountains). Furthermore, in these parts of the world, it is not unusual that the problem of daily water supply is cause of bigamy.

Due to their key function in everyday life especially in rural areas, and the need for neutralising gender specified roles in order to guarantee a sustainable development, the involvement of women in the development of a sane water economy is indispensable.

1.2.2 Technology transfer and appropriate technologies

Many modern technologies are developed in the 'North' and are available for the Southern countries only to a limited extend. Only an infinitely small part of technology-development- is adapted to the needs of people in the south. The North-South Commission under Willy Brandt came to the conclusion that 'one could say that the decisive weakness - of developing countries - is the lacking access to technology and its adeptness'. A lot of environmental technologies are too expensive to be applied for developing countries. They are sold on credits to these countries, and their employment is questionable because funds for effective operation are missing.

The north is on the way to get its environmental damages caused by industrialisation under control. The technologies used here are hardly transferable to the south. Together with the partners in the south, they need to be adopted to the specific needs , they have to be payable and usable. The EEET aims to identify, develop and transfer such technologies in cooperation with its Chinese partners. It is the aim to initiate a technology transfer which supports sustainable conservation of the environment and allow the industry profitable and environmentally sound progress, and which secures a worthy-living world to people. The emphasis is laid on technologies of water- and energy-economics.

1.2.3 The concept of integrated development

The need to elevate the rural population living conditions is fundamental to choosing this approach. This has necessitated that technologies powered by renewable energies be used as a ‘core’ of a wider range of activities, if a meaningful improvement in living standards to be achieved. The reason can be found in the mechanism of interactive problem factors in the project areas. Problem analyses showed that problem causes and effects exchange roles to form a closed circle. For instance, supplying water for irrigation or households would not bring the required results, when wastewater pours in the water source feeding the Hydraulic Ram, thus water bypasses must be built. In order to tackle the problem nature, a comprehensive approach that would address this mechanism had to be used. The same is true for most of the other project components. The integrated socio-economic and hygienic components are based on this factor.

Based on this concept, the Bremen Overseas Research and Development Association - BORDA in Germany, the Zhejiang Provincial Science and Technology Commission - ZPSTC - have been co-operating together for a long time to improve the living conditions of people in rural areas and to promote the local sustainable socio-economic development. The integrated development project includes many aspects to improve not only the technical infrastructure but also the social capabilities, such as:

- Water supply for the irrigation to improve the agriculture;
- Water supply for a decentralised domestic use;
- Income generation for local farmers, including the technical training and provision of market information;
- Water resource protection;
- Garbage collection and treatment in the villages;
- Local renewable energy utilisation such as, solar thermal energy, small and/or mini hydraulic power generation and biomass utilisation;
- Rise of farmers' living standard, especially improvement of women's economic level and working conditions;
- Protection of the environment;
- Improvement of hygiene and sanitation conditions, raising the awareness of rural people towards environmental and hygienic issues.

In the integrated development activities, the hydraulic ram plays an important role, not only for the conventional energy, but also for

- Raising living standard of the people;
- Promotion of the agricultural production;
- Improvement of the hygienic and sanitation conditions;
- Easing the domestic work for women, thus neutralise gender defined roles, etc..

In a word, it contributes to the sustainable rural development.

1.2.4 Energy for the future

Sufficient energy and an optimal infrastructure are the basic preconditions for economic growth. The fossil energies have been considered the optimum commercial energy agent for a long time. These energies will not be available endlessly and cause enormous damages to the environment. Nuclear energy has proved to be inadequate due to doubtful control and a seemingly safe but perpetual storage of radioactive waste.

From the present point of view, we are in search of alternatives. Renewable energy from biomass through gasification, water through conversion of potential energy to kinetic energy, use of thermic and photovoltaic energy, and wind power are energy sources with growing utility. However, at present, they cannot meet the requirements of human urban centres and of industry.

Science has been able to develop procedures which considerably reduce the consumption of fossil energy in combustion engines. The application of hydrogen through decomposition of water (H_2O) to its basic elements hydrogen and oxygen surely is an important method of future energy supply, although, it is presently still in an experimental phase.

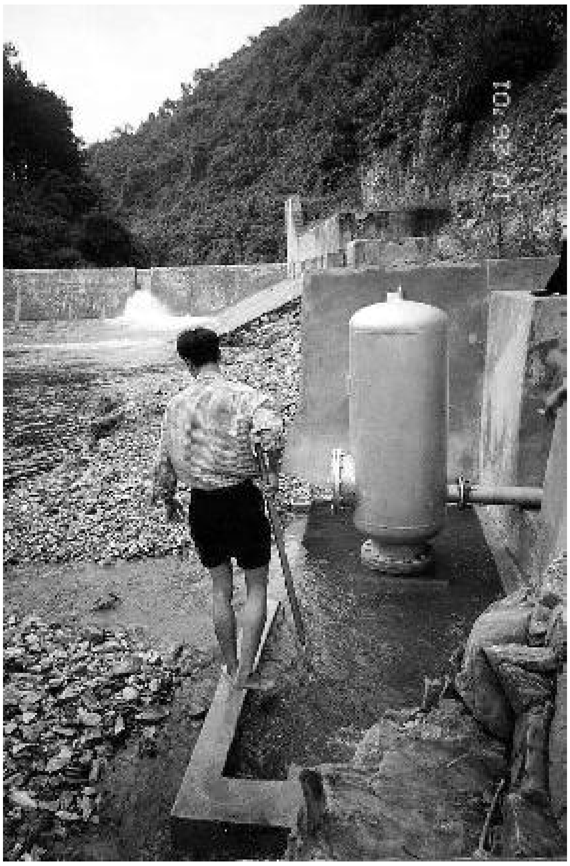
In order to meet the demand for an-environmentally-just development with a corresponding energy management, today, renewable energies are used to allow a decentralised development; for example the Hydraulic Ram to ‘pump’ water to a higher level, or biogas plants to supply people limitedly or individually with combustible energy, here methane gas.

The search for appropriate energy supply probably has just begun. The question arises, how much time is left for us.

This general excursion should have made clear that the use of appropriate technologies, like the Hydraulic Ram, can be a small contribution to sustainable development of the environment. It could form the only alternative bringing the individual user a socio-economic development, especially in undeveloped regions, often represents the only alternative for socio-economic development. BORDA’s joint projects for the dissemination of the Hydraulic Ram, especially in China, could prove that this technology helps securing crops and sustainably improves the living standard for many people. It has, however, to be remarked that for a true socio-economic development technology needs to reliable. And this is not yet enough. The users must be able to conceive the utilization of the technology, and the projects have to keep what they have promising in order to reach a wide-spread dissemination.

1.3 Situation and prospects of energy production and supply in China

China is a developing country covering 9.6 million square kilometres with a population over 1.2 billion people. The area includes the tropical climate zone (32%), subtropical climate zone (15%), sub-arid climate zone (22%) and arid climate zone (31%).



Utilisation of renewable energy resources can help to fill the gab between energy supply and demand

Since the 1980s, economic development has accelerated due to the implementation of the economic reform policy and opening to the outside world. Consequently, energy consumption has also increased. Table 1 and Table 2 in appendix 1 show the energy production and consumption from 1980-1998. Fig. 1.2.1 shows the difference between energy production and consumption.

Table 1 energy production and structure

year	***total energy production***	***percentage of total energy production***			
	(106 C.E.T.)	**coal %**	**crude oil %**	**natural gas %**	**hydro-power %**
1980	637.4	69.4	23.8	3.0	3.8
1984	778.6	72.4	21.0	2.1	4.5
1985	855.5	72.8	20.9	2.0	4.3
1986	881.2	72.4	21.2	2.1	4.3
1987	912.7	72.6	21.0	2.0	4.4
1988	958.0	73.1	20.4	2.0	4.5
1989	1016.4	74.1	19.3	2.0	4.6
1990	1039.2	74.2	19.0	2.0	4.8
1991	1048.4	74.1	19.2	2.0	4.7
1992	1072.6	74.3	18.9	2.0	4.8
1993	1112.6	73.8	18.6	2.0	5.6
1994	1187.3	74.6	17.6	2.0	5.8
1995	1290.3	75.3	16.6	1.9	6.2
1996	1326.2	75.2	17.0	2.0	5.8
1997	1324.1	74.1	17.3	2.1	6.5
1998	1240.0	72.0	18.5	2.4	7.1

Source: China Statistical Yearbook 1995-1999

Table 2 energy consumption since 1980

year	***total energy consumption***	***percentage of total energy consumption***			
	(106 C.E.T.)	**coal %**	**crude oil %**	**natural gas %**	**hydro-power %**
1980	602.8	72.2	20.7	3.1	4.0
1984	709.0	75.3	17.4	2.4	4.9
1985	766.8	75.8	17.1	2.2	4.9
1986	808.5	75.8	17.2	2.3	4.7
1987	866.3	76.2	17.0	2.1	4.7
1988	930.0	76.2	17.0	2.1	4.7
1989	969.3	76.0	17.1	2.0	4.9
1990	987.0	76.2	16.6	2.1	5.1
1991	1037.8	76.1	17.1	2.0	4.8
1992	1091.7	75.7	17.5	1.9	4.9
1993	1117.7	72.8	19.6	2.0	5.6
1994	1227.4	75.0	17.4	1.9	5.7
1995	1311.8	74.6	17.5	1.8	6.1
1996	1389.5	74.7	18.0	1.8	5.5
1997	1381.7	71.5	20.4	1.7	6.2
1998	1360.0	71.6	19.4	2.1	6.5

Source: China Statistical Yearbook 1995-1996

Generally, Eastern China is more economically developed and has a denser population than the western part of the country. Therefore, the East consumes much more energy than the West. But the proven fossil energy reserves are mainly located in the west, particularly coal mines.

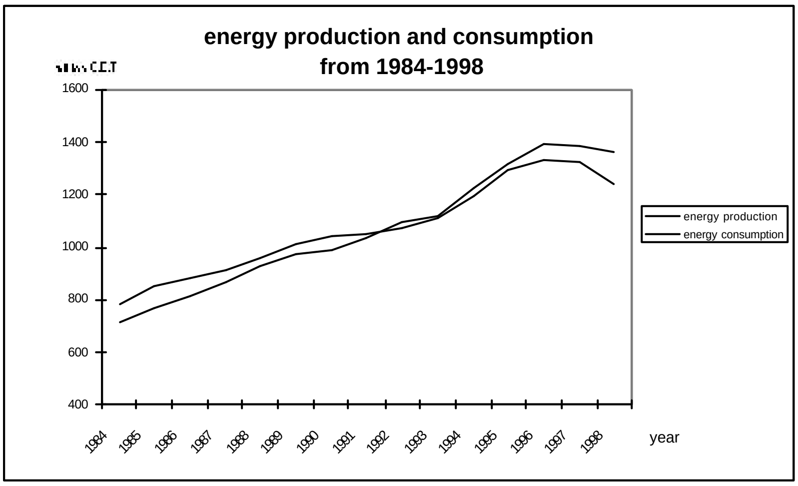


Fig. 1.2.1   energy production and consumption in China

For instance, Zhejiang Province produces only 0.34% of the total primary energy in China, but consumes 2.61%. Jiangsu Province and Shanghai Municipality produce only 1.85% and 0%, but they consume 5.92% and 3.21% respectively. Zhejiang, Jiangsu Provinces and Shanghai Municipality are located in eastern China. But Shanxi Province, northwest China, produces around 19% of the primary energy and only consumes around 5% (Source: China Statistical Yearbook 1995).

Eastern China's energy supply is influenced by two factors, i.e. limited primary energy reserves and a limited, long-distance transportation infrastructure. China's energy supply as a whole gives not an optimistic picture. Table 3 and Fig 1.2.2 show the increased consumption of coal, oil and electricity. Fig. 1.2.1 shows that since 1992, due to its fast economic development, China has become a net energy importer. If there are no measures to improve the efficiency of conventional energy utilisation and to develop and utilise renewable energy resources, the gap between energy supply and demand will continue to prevail and widen.

Table 3 increase of coal, oil and electricity consumption from 1990-1998

year	***Coal (106tons/106CET)***	***Oil (106tons/106CET)***	***Electricity (109kWh/106CET)***
1990	1055.2 / 753.7	114.9 / 164.1	623.0 / 76.6
1991	1105.7 / 789.8	124.2 / 177.5	674.1 / 82.2
1992	1140.8 / 814.9	133.5 / 190.7	758.9 / 93.2
1993	1139.2 / 813.7	313 / 219.1	835.3 / 102.6
1994	1285.3 / 918.1	149.6 / 213.7	926.0 / 113.8
1995	1370 / 978.6	325.2 / 227.6	1002.3 / 123
1996	1453 / 1038	357.3 / 250.1	1076.4 / 132.2
1997	1383 / 988	402.7 / 281.9	1128.4 / 138.6
1998	1363.3 / 973.8	376.9 / 268.3	1161.1 / 142.6

Source: China Statistical Yearbook 1995-1996

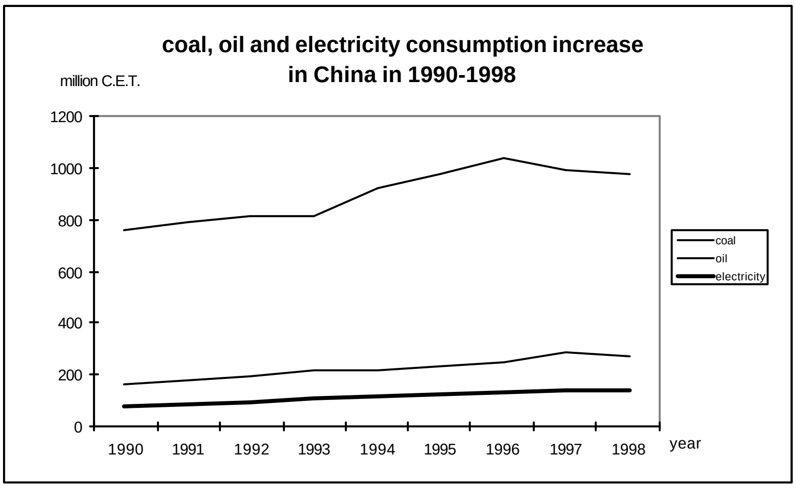


Fig. 1.2.2 coal, oil and electricity consumption increase in China

Table 4 energy consumption and elastic coefficient

year	*Growth rate of energy consumption over preceding year (%)*	*growth rate of electricity consumption over preceding year (%)*	*growth rate of GDP over preceding year (%)*	* *elastic coefficient of energy consumption*	** *elastic coefficient of electricity consumption*
1986	5.4	9.5	8.8	0.61	1.08
1987	7.2	10.6	11.6	0.62	0.91
1988	7.3	9.7	11.3	0.65	0.89
1989	4.2	7.3	4.1	1.02	1.78
1990	1.8	6.2	3.8	0.47	1.63
1991	5.1	9.2	9.3	0.55	0.91
1992	5.2	11.5	14.2	0.37	0.81
1993	2.8	9.5	13.5	0.21	0.70
1994	6.0	10.5	12.6	0.48	0.83
1995	6.9	8.2	10.5	0.66	0.78
1996	5.9	7.4	9.6	0.61	0.77
1997	-0.6	4.8	8.8	-	0.55
1998	-1.6	2.9	7.8	-	0.37

* : In order to quantify the relationship between the national economic development and the energy consumption increase, Elastic Coefficient of Energy Consumption is defined as an indicator. The formula is:

$$C_{en}=R_{en}/R_{ne}$$

where:

C_{en}: elastic coefficient of energy consumption
R_{en}: average annual growth rate of energy consumption
R_{ne}: average annual growth rate of national economy

**: In order to quantify the relationship between the national economic development and the electricity consumption, the Elastic Coefficient of Electricity Consumption is defined as an indicator. The formula is:

$$C_{el}=R_{el}/R_{ne}$$

where:

C_{el}: elastic coefficient of electricity consumption
R_{el}: average annual growth rate of electricity consumption
R_{ne}: average annual growth rate of national economy

1.4 *Increasing energy demand and environmental problems*

Table 2 in this chapter shows the increase in conventional energy consumption. The trend towards an increased energy demand is the results of the increased population and socio-economic development. Table 4 on the previous page refers to the energy consumption during the development of the national economy.

The GDP’s average annual increase rate from 1986-1998 was 9.7%, and energy consumption increased at an average of 4.4% per year. The increased energy demand and consumption results in an energy shortage and presents environmental problems. The energy shortage hinders socio-economic development. However, problems of the environment are an even worse aspect than the energy supply.

75% of the energy consumed in China is generated by coal. Burning coal produces more harmful exhaust gas, such SO_2, NOx, CO and CO_2 and dusts than oil and natural gas. These harmful gases damage the ecological environment and cause serious losses to socio-economic development negatively affecting people’s lives. Therefore, even if the conventional energy resources posed no limitations to development, the environmental aspect of the problem would still form a great hazard.

Electricity consumption is increasing faster than other energy forms. The average annual increase rate of electricity consumption from 1985-1998 was 9%. The electricity generated from hydraulic power stations was only around 20%. The remaining electricity was generated by coal-fire powered plants. These plants are the main polluters emitting CO_2 and SO_2. The pollution from power plants will worsen with the rapidly increasing electricity demand if measures are not taken.

Consequently, these have been reflected in the **China’s Agenda 21 i.e. ‘White Paper on China’s Population, Environment and Development in the 21st Century’.** It has four main sections:

- Overall strategies for sustainable development
- Sustainable development of the society
- Sustainable development of the economy
- Resources and environmental protection

Within **China's Agenda 21**, nine priority programs are stated. Clean energy including renewable energy, energy saving, conservation and sustainable utilisation of natural resources, and environmental pollution control are listed as Priority 4, Priority 5 and Priority 6, respectively.

1.5 Unbalanced development of economy and energy supply in Eastern and Western China

China is huge. Economic development differs according to different climates, geography, natural resources, traditions and economic levels. The differences have been growing since the beginning of the 80's when the economic reform and opening policy were implemented. The coastal areas in the eastern part of China have more favourable means for transportation and communication than areas in the west. The economy of the East is booming.

Table 5 refers to the GDP per capita in municipalities, provinces and autonomous regions of China and is an indicator to the economic levels. Table 6 refers to the average annual income per capita in the municipalities, provinces and autonomous regions' rural areas and is the key data reflecting the living standard.

Table 5 and Table 6, indicate that the economy in the eastern part of China, such as Zhejiang, Jiangsu, Fujian, Guangdong Provinces and Shanghai Municipality, is much more developed than the western part.

The increased growth rate of the GDP (gross domestic products) caused a high increase of energy consumption. But unfortunately, these regions have few conventional energy reserves, and the self-supply primary energy ratio of the total energy consumption is very low. For instance, the self-supply primary energy ratio is only around 10% in Zhejiang Province, 40% in Jiangsu Province and 0% in Shanghai.

Most of the energy consumed in these provinces is from western China, about 2000 km away. The limited transportation system has been put under pressure to meet the increasing energy demand. Due to these two factors, i.e. the limited primary conventional energy reserves and limited transportation, energy supply has become a serious obstacle since the 80's.

Table 5 GDP per capita in municipalities, provinces and autonomous regions

Unit: yuan RMB

Region	***1990***	***1991***	***1992***	***1993***	***1994***
Beijing	5055	5474	6435	7703	9636
Tianjin	3621	3771	4477	5752	7755
Hebei	1581	1724	2037	2669	3362
Shanxi	1563	1592	1913	2337	2804
Inner Mongolia	1559	1647	1911	2388	3017
Liaoning	2866	3008	3668	4975	6354
Jilin	1775	1847	2204	2811	3764
Heilongjiang	2189	2306	2395	3309	4408
Shanghai	6256	6700	8285	11131	14542
Jiangsu	2123	2340	3091	4300	5779
Zhejiang	2215	2574	3223	4477	6211
Anhui	1192	1152	1373	1815	2500
Fujian	1809	2020	2528	3598	5295
Jiangxi	1175	1240	1463	1824	2570
Shangdong	1872	2113	2551	3216	4466
Henan	1140	1193	1444	1859	2436
Hubei	1588	1657	1951	2520	3285
Hunan	1273	1294	1592	2025	2666
Guangdong	2416	2765	3515	4882	6340
Guangxi	1089	1199	1476	2013	2764
Hainan	1599	1788	2649	3687	4655
Sichuan	1197	1269	1477	1870	2477
Guizhou	837	893	1011	1221	1507
Yunnan	1313	1368	1615	2006	2473
Tibet	1366	1351	1460	1976	1941
Shaanxi	1314	1388	1587	1950	2432
Gansu	1138	1188	1373	1587	1900
Qinghai	1608	1654	1898	2347	2916
Ningxia	1470	1495	1707	2089	2659
Xinjiang	1937	2167	2545	3141	4128

Table 5 continued

Region	**1995**	**1996**	**1997**	**1998**
Beijing	8257	12833	14698	16142
Tianjin	9768	11629	13016	13964
Hebei	4428	5324	6059	6479
Shanxi	3550	4207	4712	5048
Inner Mongolia	3647	4269	4706	5084
Liaoning	6826	7672	8434	9338
Jilin	4352	5123	5506	5892
Heilongjiang	5443	6445	7221	7508
Shanghai	17403	20452	23063	25193
Jiangsu	7296	8445	9346	10025
Zhejiang	8163	9547	10458	11193
Anhui	3332	3854	4358	4537
Fujian	6674	7923	9142	10095
Jiangxi	2966	3696	4133	4419
Shangdong	5747	6821	7570	8104
Henan	3300	3992	4413	5677
Hubei	4143	5099	5875	6271
Hunan	3435	4118	4630	4939
Guangdong	7836	9365	10375	11087
Guangxi	3296	3700	3922	4071
Hainan	5030	5307	5516	5829
Sichuan	3121	3643	4438 (Chongqin) 3938 (Sichuan)	4671 (Chongqin) 4216 (Sichuan)
Guizhou	1796	2008	2199	2301
Yunnan	3024	3690	4016	4329
Tibet	2333	2654	3104	3618
Shaanxi	2846	3317	3714	3842
Gansu	2272	2895	3133	3452
Qinghai	3437	3762	4074	4377
Ningxia	3309	3716	3980	4228
Xinjiang	4968	5401	6114	6392

Source: China Statistical Yearbooks 1992-1999

Table 6 average annual income per capita in rural areas of municipalities, provinces and autonomous regions

Unit: yuan RMB

Region	***1990***	***1991***	***1992***	***1993***	***1994***
Beijing	1297.05	1422.37	1571.56	1882.58	2400.69
Tianjin	1069.04	1168.53	1309.01	1835.71	621.67
Hebei	621.67	657.38	682.48	803.80	1107.25
Shanxi	603.51	567.90	627.01	718.33	884.20
Inner Mongolia	607.15	517.99	672.17	777.95	969.91
Liaoning	836.17	896.71	995.10	1160.98	1423.45
Jilin	803.52	748.33	807.41	891.61	1271.63
Heilongjiang	758.86	734.80	949.20	1028.36	1393.58
Shanghai	1907.32	2003.38	2225.87	2726.98	3436.61
Jiangsu	959.06	920.72	1060.71	1266.97	1831.53
Zhejiang	1099.04	1210.77	1359.13	1745.94	2224.64
Anhui	539.16	446.05	573.58	724.50	973.20
Fujian	764.41	850.05	984.10	1210.51	1577.74
Jiangxi	669.30	702.53	768.41	869.81	1218.19
Shangdong	680.18	764.04	802.90	952.74	1319.73
Henan	526.95	539.29	588.48	695.85	909.81
Hubei	670.80	626.92	677.82	783.18	1172.74
Hunan	664.24	688.91	739.42	851.87	1155.00
Guangdong	1043.03	1143.06	1307.65	1674.78	2181.52
Guangxi	639.45	657.74	731.69	892.07	1107.02
Hainan	696.22	730.08	842.79	991.99	1304.52
Sichuan	557.76	590.21	634.31	698.27	946.33
Guizhou	435.14	465.53	506.13	579.67	786.84
Yunnan	540.86	572.58	617.98	674.79	802.95
Tibet	649.71	706.67	829.66	889.49	975.95
Shaanxi	530.80	533.96	558.79	652.99	804.84
Gansu	430.98	446.42	489.47	550.83	723.73
Qinghai	559.78	555.56	603.40	672.56	869.34
Ningxia	578.13	589.98	591.01	636.39	866.97
Xinjiang	683.47	703.17	740.44	777.62	946.82

Table 6 continued

Region	***1995***	***1996***	***1997***	***1998***
Beijing	3224	3562	3662	3952
Tianjin	2406	3000	3244	3396
Hebei	1669	2055	2286	2405
Shanxi	1208	1557	1738	1859
Inner Mongolia	1208	1602	1780	1981
Liaoning	1757	2150	2301	2580
Jilin	1610	2126	2186	2384
Heilongjiang	1766	2182	2308	2253
Shanghai	4246	4846	5277	5407
Jiangsu	2457	3029	3270	3377
Zhejiang	2966	3463	3684	3815
Anhui	1303	1608	1809	1863
Fujian	2049	2492	2786	2946
Jiangxi	1537	1870	2107	2048
Shangdong	1715	2086	2292	2453
Henan	1232	1579	1734	1864
Hubei	1511	1864	2102	2172
Hunan	1425	1792	2037	2065
Guangdong	2699	3183	3468	3527
Guangxi	1446	1703	1875	1972
Hainan	1520	1746	1917	2018
Sichuan	1158	1453	1643 (Chongqin) 1681 (Sichuan)	1720 (Chongqin) 1789 (Sichuan)
Guizhou	1087	1277	1299	1334
Yunnan	1011	1229	1376	1387
Tibet	1200	1353	1195	1232
Shaanxi	963	1165	1273	1406
Gansu	880	1101	1185	1393
Qinghai	1029	1174	1321	1425
Ningxia	999	1398	1513	1721
Xinjiang	1136	1290	1504	1600

Source: China Statistical Yearbooks 1992-1999

1.6 Situation and prospects of rural energy supply and consumption

From the beginning of the 50's to the end of the 70's, China had a planned economy, meaning that the economic activities from production to market were pre-planned. The energy supply for the urban industries and urban domestic use were also strictly pre-planned.

Enterprises received an energy supply quota with a fixed price according to production planning. Families in the cities and towns received a fixed quota of fuel. At that time, electricity consumption was not restricted by a limit because there was little demand for electricity. Most families had few electrical appliances, perhaps only the most basic (one or two lamps for lighting).

80% of China's population live in rural areas. In the planned economy, an energy supply for the domestic sector in rural areas was not included. Fuel used in daily life within the households came form firewood and straw in most places. In the Western areas, for instance in Qinghai, Gansu and Tibet, cattle dung was consumed. Conventional energy for cooking and heating rural homes was not available.

In most regions, fuel for the farmers' daily consumption depended on forest-cut firewood and agricultural residues, such as straw and crop stems which negatively affected the ecological cycle, caused soil erosion and reduced land fertility.

These environmental problem came to the people's attention in the early 80's. Some technologies to reduce fuel consumption were developed, such as firewood-saving stoves, small biogas digesters, small and mini-hydraulic power stations. For practical use, firewood-saving stoves achieved remarkable results in rural energy conservation. But the demand for energy in the rural areas continues to grow due to the increased population and the farmers' increasing income. Thus, the energy supply shortage still exists.

With the expansion of the market economy, which started at the beginning of the 80's, more conventional fuel became available at market price. Farmers living near cities and towns tend to consume more conventional energy, such as coal bricks and LPG because these fuels are more convenient, cleaner and easier to use. The potential demand on these fuels and electricity is increasing. From 1990 to 1993, the expenditure per capita on fuel in rural areas increased from 26.46 yuan to 37.54 yuan RMB. The average annual increase rate was 12.3%.

With the tendency of development of small towns and cities and the improvement of the farmer's living standard, the demand for energy in the rural areas will put even greater pressure on the existing conventional energy supply, if there is no alternative to meet the farmer's daily energy demand.

The demand in the urban area is more intensive and centralised than in the rural areas. It is difficult to develop alternative energy to replace the conventional energy demand. But in the rural areas, the population density is much lower and the natural resources are more available than in the urban areas. There are more possibilities in rural areas to use local resources to meet the energy demand through the development of technologies powered by renewable energies. The conventional energy supply alone is not sufficient to meet the rural people's increasing demand for a clean and a convenient energy. A hybrid energy supply system with various technologies for utilising local renewable energy resources is essential for a local socio-economic development.

1.7 Rural energy policy and environmental development in China

Since the beginning of the 80's, the Government policy on rural energy and environmental development emphasised being 'based on the local condition to efficiently utilise the local energy resources'. The solution is not to depend on the conventional energy supply, but to use the local renewable energy resources as much as possible, such as solar, wind, small and mini hydraulic energy, biomass, etc. There are several advantages to the use of local resources:

- to reduce pressure on the conventional energy supply;
- to reduce the energy loss due to long distance transportation;
- to avoid environmental pollution caused by conventional energy combustion;
- to have less intensive capital investment for the establishment of decentralised energy supply systems;
- to easily plan at a local level;
- to use the local resources efficiently and rationally.

Consequently, the government policy on rural energy and environmental development has pledged to:

- put focus on the development of the various appropriate technologies for renewable energy utilisation;
- demonstrate these technologies;
- subsidise these technologies in their dissemination process;
- train people to be aware of the importance of environmental protection and energy conservation and stimulate acceptance of appropriate technologies which uses local renewable energy;
- reduce taxes for the production of equipment and devices that utilise local renewable energy resources;
- provide preferential loans for the production and installation of facilities that use the local renewable energy resources.

China's Agenda 21, issued by the Chinese Government, puts the utilisation of renewable energy resource as a priority program and alternative for achieving an overall socio-environmental protection.

1.8 Rural energy balance and potential of the hydraulic ram

1.8.1 Situation and prospects of rural energy supply in Zhejiang Province

The state of the conventional energy supply does not give rise to optimism if we review the energy supply compared to consumption in the last several years, 1990-1998. Fig. 1.7.1.1 refers to coal production from 1990 to 1998 (million tons).

In this period, the average annual increase rate of coal consumption in Zhejiang Province was 8.4%. In the chapter above, it was mentioned that the self-supplied coal made up only 6% of the total coal consumption, and self-supplied coal production tended to decrease due to the limited coal reserves.

Also the electricity supply in Zhejiang Province does not show an optimistic picture. Fig. 1.7.1.2 shows the electricity generation in Zhejiang Province from 1990 to 1998.

The Fig. 1.7.1.3 refers to coal consumption in Zhejiang Province in 1990-1998 and Fig. 1.7.1.4 shows the gap between the power generation and consumption in the same period in Zhejiang Province.

The conventional energy supply does not meet the increasing demand, not of industries and not of households, neither in urban nor in rural areas. Since the rural conventional energy supply (except electricity and diesel for irrigation) was not part of government planning for a long period, the energy supply networks in the rural areas did not function as efficient, when compared to those of urban areas. These networks cannot satisfy the needs of energy users. Thus, in the rural areas, the energy problem is not only insufficient energy sources (quantity), but also poor supply systems.

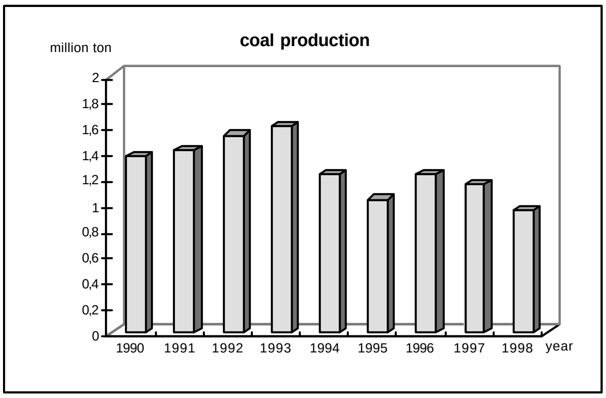


Fig. 1.7.1.1 coal production in Zhejiang Province

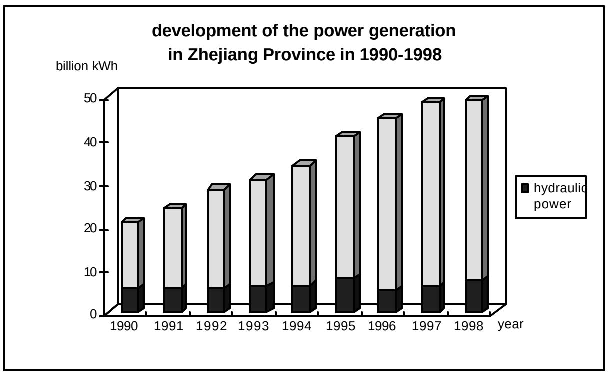


Fig. 1.7.1.2 electricity generation in Zhejiang Province

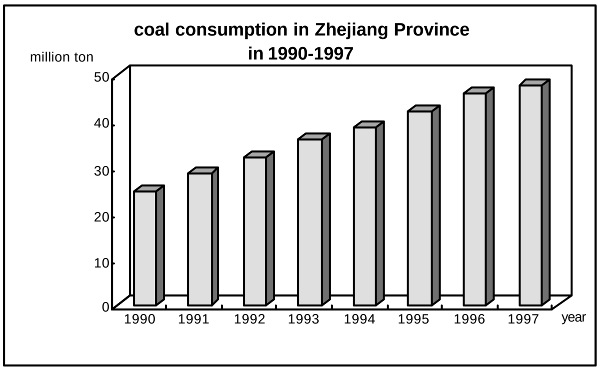


Fig. 1.7.1.3 coal consumption in Zhejiang Province

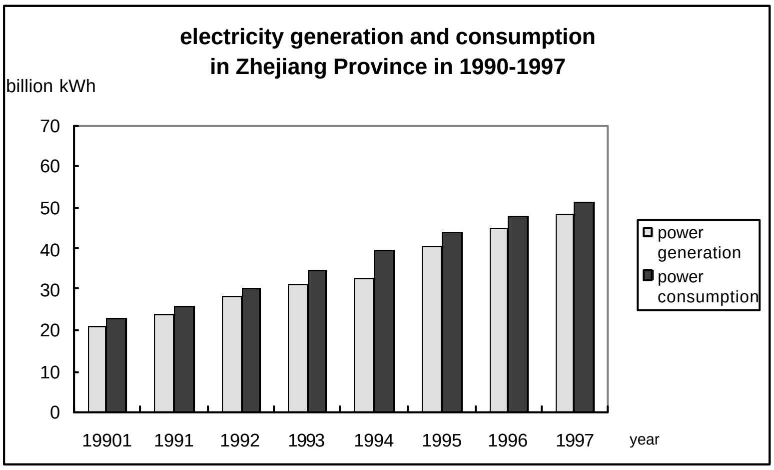


Fig. 1.7.1.4 Electricity generation and consumption in Zhejiang Province

1.8.2 Increasing energy demand and environmental pollution caused by energy consumption

There was a rapid economic development in rural areas around Zhejiang. Especially industries, these developed at an unimaginable speed since 1980. In the beginning of the 80's, the gross output value of rural industries was only 19.8% of the Province's overall industries. But in 1998, the gross output value of rural industries was 86.5%. The average annual increase rate of rural industries' gross output value was 136%, at an incredible speed.

Consequently, with the fast development of the rural industries, the energy consumption increased rapidly. Fig. 1.7.2.1 and Fig. 1.7.2.2 show the increase of the coal and electricity consumption in Zhejiang's rural industries from 1990 to 1997.

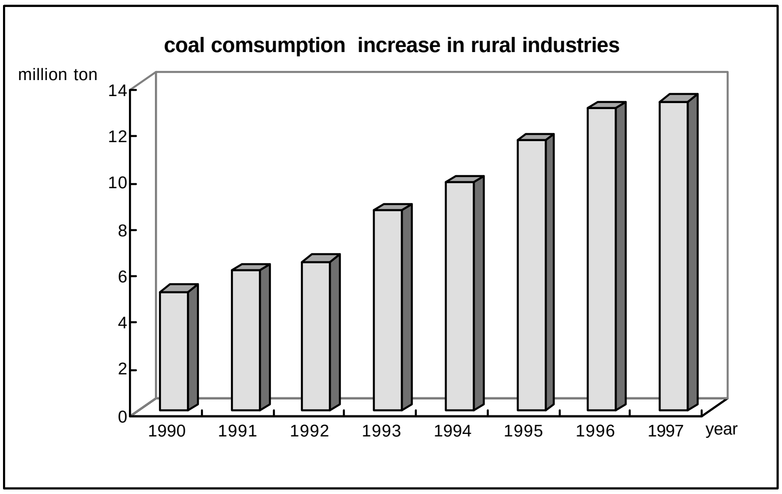


Fig. 1.7.2.1 coal consumption increase in rural industries

Rural households' conventional energy demand also increased due to higher incomes and improved living standards. Table 1.7.2.1 shows the average annual farmer's expenditure per capita for electricity and commercial fuel and its increasing demand from 1990-1994.

Table 1.7.2.1 farmer's fuel and electricity consumption per capita

	1990	*1991*	*1992*	*1993*	*1994*
Fuel (kg)	190.86	197.2	195.27	165.01	213.78
Electricity (kWh)	7.52	9.65	12.07	14.25	19.90

Source: Zhejiang Statistical Yearbook 1995

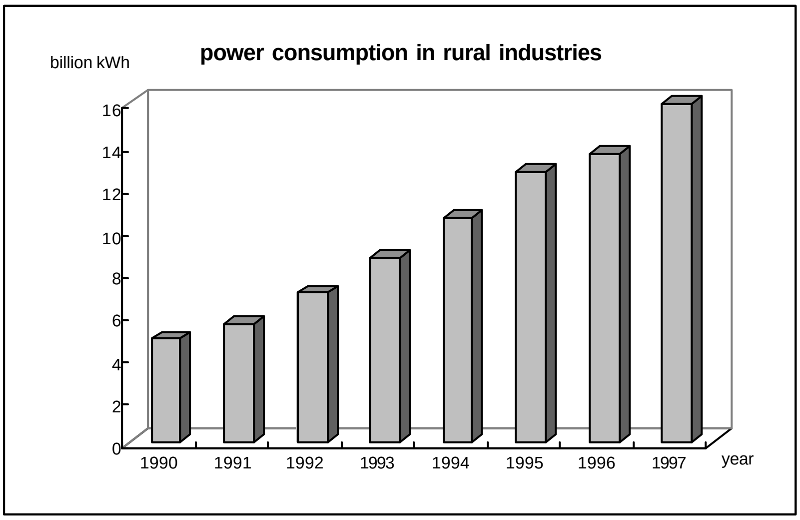


Fig. 1.7.2.2 electricity consumption increase in rural industries

Table 1.7.2.2 energy consumed in family groups with different incomes

	low income		medium income			high income	
	group 1	**group 2**	**group 1**	**group 2**	**group 3**	**group 1**	**group 2**
average income (yuan RMB)	2654	3348	3980	4774	5819	6978	9349
cash payment for electricity, fuel and water per capita (yuan RMB)	129	136	143	147	163	167	178
electricity consumed per capita (kWh)	155	174	190	195	217	238	256
coal consumed per capita (kg)	81	49	36	34	30	24	17
LPG consumed per capita (kg)	17.8	23.9	24.4	26.2	28.5	30.4	33.3
city gas consumed per capita (kg)	2	2	6	9	15	15	16
in total per capita (MJ)	**3026**	**2680**	**2537**	**2625**	**2793**	**2822**	**2875**

Source: China's Statistical Yearbook 1995

Traditionally, farmers mainly used forest-cut firewood, and/or straw collected from the fields. The only cost for the farmers was their own labour. But with the increase of income, more and more farmers could afford to buy commercial energy, such as coal and LPG, which is convenient and clean to use compared to firewood or straw.

The urban population with a higher income, tend to use more convenient and cleaner energy, such as electricity and LPG, and less inconvenient and comparatively dirty energy, such as coal. They also consume less non-commercial energy, such as firewood and straw. Table 1.7.2.2, reflects data collected in 1994. With the increase of income, people used less coal, but more electricity, LPG and city gas. It can be inferred that having more income, farmers used more commercial energy and less firewood and straw.

Rural traditional enterprises also consumed conventional energy, such as electricity, coal and diesel. But from the statistic data, (see Table 1.7.2.3, Fig. 1.7.2.3 and Fig. 1.7.2.4) the energy demand didn't tend to increase quickly.

Table 1.7.2.3 coal and electricity consumption in the rural traditional production

	1990	**1991**	**1992**	**1993**	**1994**
coal consumption (10^6 tons)	0.33	0.34	0.39	0.31	0.32
electricity consumption (10^9 kWh)	1.32	1.44	1.54	1.60	1.23

Source: Zhejiang Statistical Yearbook 1995

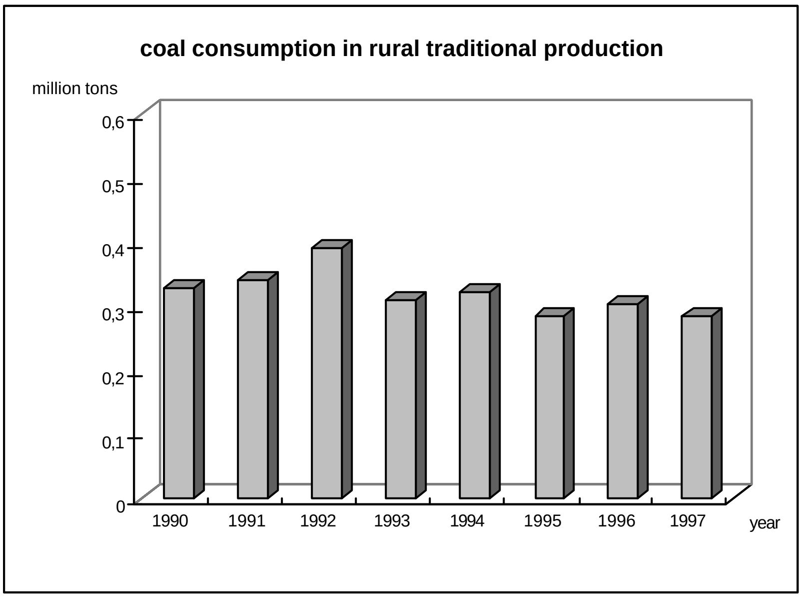


Fig. 1.7.2.3 coal consumption in rural traditional production

The consumption in rural industries and households caused an increase in the energy demand. The annual coal consumption increase rate was 12.6% from 1990 to 1997**,** and the annual electricity consumption increase rate reached 16% in the same period for rural industries. The increase rate of commercial energy consumed in households in the same period reached also about 28% annually. These two energy users consumed the lion's share of the total energy supply.

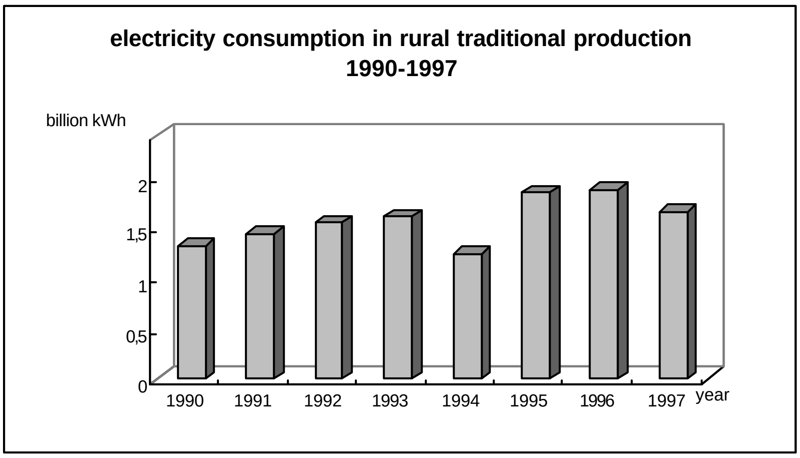


Fig. 1.7.2.4 electricity consumption in rural traditional production

The other severe problem caused by energy consumption is environmental pollution. These problems differ from the ecological problems of the late 70's and early 80's. At that time, the main ecological problems resulted from the practice of excessive exploitation of the natural forest and vegetation resources by the rural peoples, and the misuse of the agricultural residues due to the increasing fuel demand.

Trees and the vegetation were overgrazed to be used as firewood. Farmers directly burned agricultural residues, such as straw and stems for fuel. This over-cutting and direct burning led to soil erosion and deforestation. Recently, rural industries and households have been using more and more conventional energy. The more recent ecological and environmental problems have been caused by the pollution because of conventional energy consumption, especially coal.

Steps must be taken to conserve energy and vitalise the utilisation of local renewable energy for the benefit of rural industries and households in order to ease the conventional energy supply shortage and reduce air pollution. The potential of the utilisation of renewable energy by rural industries is more difficult than that of the household because rural industry is more energy intensive. For rural industries, a strategy aiming at energy conservation will be more effective. The energy used in household is less intensive. There are many ways to replace conventional energy with local renewable energy resources through the utilisation of appropriate technologies.

1.8.3 Rural energy policy and environmental development

Zhejiang Province was one of the earliest provinces to pay a great deal of attention to rural energy development and environmental protection.

Because the Zhejiang Province has very limited fossil energy reserves, the energy supply cannot meet the demand. Before the 80's rural farmers did not use conventional energy. Local forest resources and agricultural residue were used for generating energy. Farmers burned firewood or straw in traditional stoves. These stoves were extremely inefficient and wasted firewood when the farmers cooked and heated their homes. Therefore, the first energy saving project aim was to develop firewood-saving stoves with a higher efficiency. The new design took several factors into consideration, such as different fuels, cooking behaviour, standardised structure and easy installation. To fully utilise local biomass resources, farmers were also encouraged to use biogas digesters.

The government also promoted other kinds of renewable energy development and made favourable policies to support the utilisation of renewable energy resource. There were two advantages. Firstly, in the Zhejiang Province, there are very rich renewable energy resources, such as wind and tidal energy on the coast and islands, and solar energy on the plains. Usages of these energies can reduce direct-burning of firewood and straw. Secondly, renewable energy utilisation has a positive impact on environment protection.

The basic principle for rural energy development is to depend on the conditions of local natural resources and utilise local renewable energy resources with the use of appropriate technologies. Favourable policies to encourage renewable energy development and energy conservation included two aspects:

- to finance devices, experiments and development of technology in their experimental stage;
- to subsidise devices, technology demonstrations and dissemination.

1.8.4 Description of achievement in the field of rural energy policy and the utilisation of renewable energies

From the beginning of the 80’s, many achievements have been obtained in renewable energy development and energy conservation in the rural areas. Several technologies were developed. These quickly proved reliable, viable and economical in the practical application and have been moderately to widely disseminated. Some of these are:

- small biogas digester for family use;
- large and medium-sized biogas plants for intensive livestock farms;
- firewood-saving stoves and coal-saving stoves;
- solar heat collectors for heating water;
- small hydraulic power stations;
- hydraulic rams for lifting water.

Some of these technologies showed technical reliability and economic viability only under certain conditions. These technologies were competitive with conventional energy and have been disseminated in suitable areas, such as:

- photovoltaic application for small power supply in remote off-grid areas;
- wind generation on islands and in remote off-grid areas.

Although there have been several pilot projects or demonstration projects in the 80's and early 90's, the following technologies need technical improvement or economic adjustment:

- power generation by tidal energy;
- floating pumps for water lifting ;
- biomass gasification;
- ocean wave energy and tidal current energy utilisation;
- solar energy used for air conditioning system.

Besides the above technologies, a great deal has been accomplished through implementing the energy resource survey, planning and management programs, and the 'Optimisation of Rural Energy Structure Study'. These projects were able to help the people:

- to understand the quality and quantity of the various renewable energy resources;
- to be aware of the suitable conditions for appropriate technology application;
- to understand the relevant situation and foresee the tendency of energy supply and demand in the rural areas and the main problems in energy supply and environment;
- to understand the nature of applying technologies of renewable energy through technical and economic analysis;
- to find a suitable approach to ease the shortage of energy supply and solve environmental problems;
- to make a suitable plan for renewable energy development combined with environment protection according to technical and socio-economic development.

The Rural Energy Balance Study for Zhejiang Province was one of these projects.

1.8.5 Results and conclusion of the rural energy balance study

Based on data analysis collected in the overall survey and detailed survey, strategies have been made to solve problems relating to the energy supply and environmental protection in the Zhejiang Province. The framework of the study is shown in Fig. 1.7.5.1.

The study's main objective was to point out short and long-term strategies for local renewable energy utilisation with the appropriate technologies for rural socio-economic development.

For the short term, the appropriate technologies according to regions were identified as follows:

- coastline and islands - wind generation;
- plains and suburbs - multi-function biogas plants, and domestic solar heat collectors;
- mountainous and semi-mountainous areas - hydraulic resource utilisation mainly through hydraulic power generation, hydraulic rams to lift water for irrigation and decentralised domestic water supply systems, households biogas digesters, and firewood-saving stoves.

For the long term, appropriate technologies were identified according to regions as:

- coastline and islands - wind generation, tidal power generation and other ocean power generation technologies;
- plains and suburbs - multi-function centralised biogas plant, biomass densification and gasification, solar heat collectors combined with electrical power or gas;
- mountainous and semi-mountainous areas - hydraulic generation and direct utilisation of hydraulic energy by hydraulic rams, floating pumps, hydraulic turbine pumps, etc.; biomass densification and gasification, decentralised biogas digesters and centralised multi-function biogas plants; fuel-saving stoves fit for densifie biomass fuel.

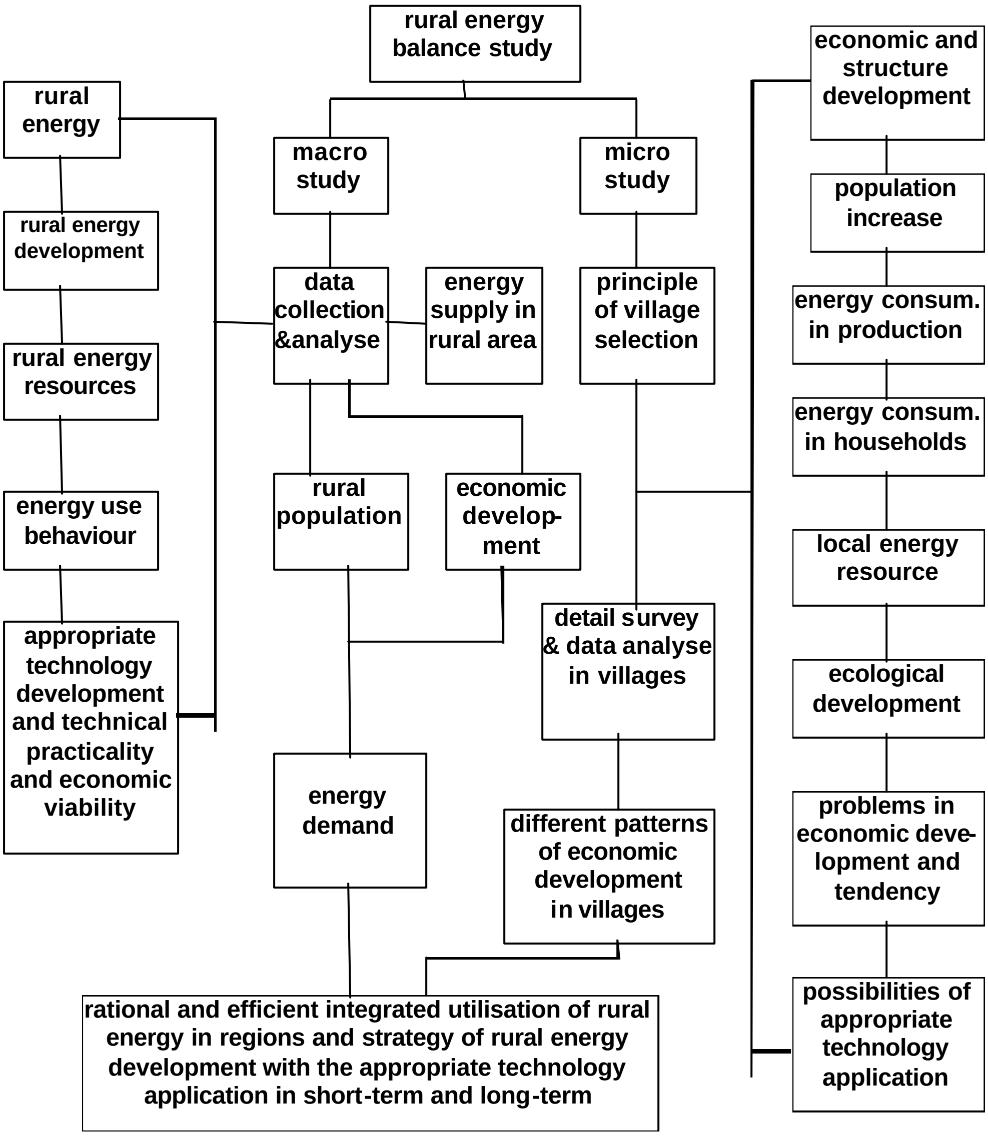


Fig. 1.7.5.1 framework of the rural Energy Balance Study in Zhejiang Province

1.8.6 Conclusion of overall potential study on the hydraulic ram application

Since the late 80’s, ZPSTC (Zhejiang Provincial Science and Technology Commission) co-operated with BORDA (Bremen Overseas Research and Development Association) to transfer the hydraulic ram technology to the Zhejiang Province. Through a demonstration and trail phase, the hydraulic ram’s ability to provide water for irrigation and tap water has brought remarkable results in the Province. Hydraulic ram site selection, installation and operational experience have been maintained by local engineers, technicians and farmers.

In the beginning of the 90’s the production of hard- and software for 4 types of hydraulic ram was transferred to Zhejiang Province, with financial and technical support from BORDA, in order to disseminate this technology on a larger scale. By 1995, two companies in Lishui could manufacture 4 types of hydraulic ram, mini-type, type 420, 630 and 840, to meet the various conditions of water resources and people’s demand.

More than 400 sets of hydraulic rams have been installed in more than 350 of villages of Zhejiang’s. The practical application of the hydraulic ram since 1989 has proven that it is a suitable technology for potable water supply and for irrigation. While mainly used for irrigation, the case of each location is checked to distinguish the priority. A good number of villages enjoyed a domestic water supply. Some hydraulic rams are used only for irrigating of orchards and dry land.

On average, one set of hydraulic ram replaces one 6 kW electric pump system. Using the hydraulic ram instead of the 6 kW electrical motor operating about 8 hours per day to supply the same amount of water, the 400 sets of hydraulic ram have saved over 6 million kWh per year. Although the quantity of the electricity saved by the hydraulic ram is negligible when compared with the total electrical power consumption in the Zhejiang Province, the saving in electrical power bills of the small village farmer is considerable. The application of the hydraulic ram profoundly improves the farmers’ living standard and the agricultural production.

A study on the potential application of the hydraulic ram in Zhejiang Province was made to further plan its dissemination in Zhejiang’s mountainous and semi-mountainous areas, as well as other provinces.

The purpose of the study was:

- to find the number of hydraulic rams needed at potential sites;
- to suggest policies at different levels to promote the dissemination of the hydraulic ram;
- to encourage the manufacturing of the hydraulic ram.

The contents of the study are:

- to make a general survey of counties in the mountainous and semi-mountainous areas of Zhejiang Province;
- to select two counties for a detailed survey, one county representing the mountainous areas and the other representing the semi-mountainous areas;
- to analyse and evaluate the data and information feedback from the counties;
- to analyse and evaluate the practical experience gained from installed hydraulic rams;
- to estimate the potential number of hydraulic rams that could be installed in the coming years in Zhejiang Province based on the detailed survey and the geographical and topographical data in the whole of the province;
- to suggest policies that support the dissemination of the hydraulic ram;
- to schedule the dissemination of the hydraulic ram and corresponding measures.

Zhejiang Province has 61 counties. The counties in the North plains and the Eastern coastal areas and islands are not suitable for the dissemination of the hydraulic ram. The potential application of the hydraulic ram is limited in those areas. Hence, the general survey focused on the counties in the mountainous and semi-mountainous areas of the Zhejiang Province. These counties make 2/3 of the Province counties. The general survey of these counties was based on their:

- geography and climate;
- socio-economic development;
- economic standard;
- production and household energy consumption;

- household, industry and agricultural water supply;
- rough estimation of the potential application of the hydraulic ram.

The general survey provided the hydraulic ram's operational potential in general but did not include detailed information e.g. the potential installation sites, which necessitated a more detailed survey. To make the detailed survey successful, several questions were important:

1. where — the selection of the counties for the detailed survey;

2. how — the method of the survey;

3. who — the personnel to conduct the detailed survey;

4. what — the questionnaires for the survey.

Mountainous and semi-mountainous areas cover approximately 70% of Zhejiang Province. The counties to be selected for the survey should reflect this geographical feature of the Province. Jingning and Jinyun countries were selected for the detailed survey because:

- 90% of Jingning and 79% of Jinyun are mountainous or semi-mountainous.
- Hydraulic rams have been in operation there since 1991. There are engineers and technicians with rich experience in selecting sites and installing the hydraulic ram.
- A detailed survey of the hydraulic resources for the small and mini-hydro power stations was conducted from 1993 to 1995. The data base for water resources was very helpful for the detailed survey.
- Engineers and technicians from the local Science and Technology Commission and the local Rural Energy Office had cooperated with the staff of the local Water Conservation Bureau regarding hydraulic power utilisation for several years. They had general information about hydraulic resources in these counties.
- Since the hydraulic ram was already introduced in these counties, staff of the local Science and Technology Commission and the local Rural Energy Office have been very active in the dissemination of the hydraulic ram. There intention was to conduct a detailed survey on the potential application, not only for the overall potential study

in Zhejiang province, but also for a further dissemination of the hydraulic ram in their own counties.

During the general survey, data and information on the socio-economic development, energy consumption, water supply for domestic use and irrigation, etc. from these two counties and other counties in Zhejiang Province, had already been collected. The focus of the detailed survey was on the hydraulic resources and the possible sites to install hydraulic rams.

Compared to the general survey questionnaires, the detailed survey was simpler but more time intensive. Most of the data and information could not be obtained from the counties statistics or yearbooks, but only by field visits to the rivers and their branches. Fig. 1.7.6.1 shows the structure of the overall potential study of the hydraulic ram dissemination in the Zhejiang Province.

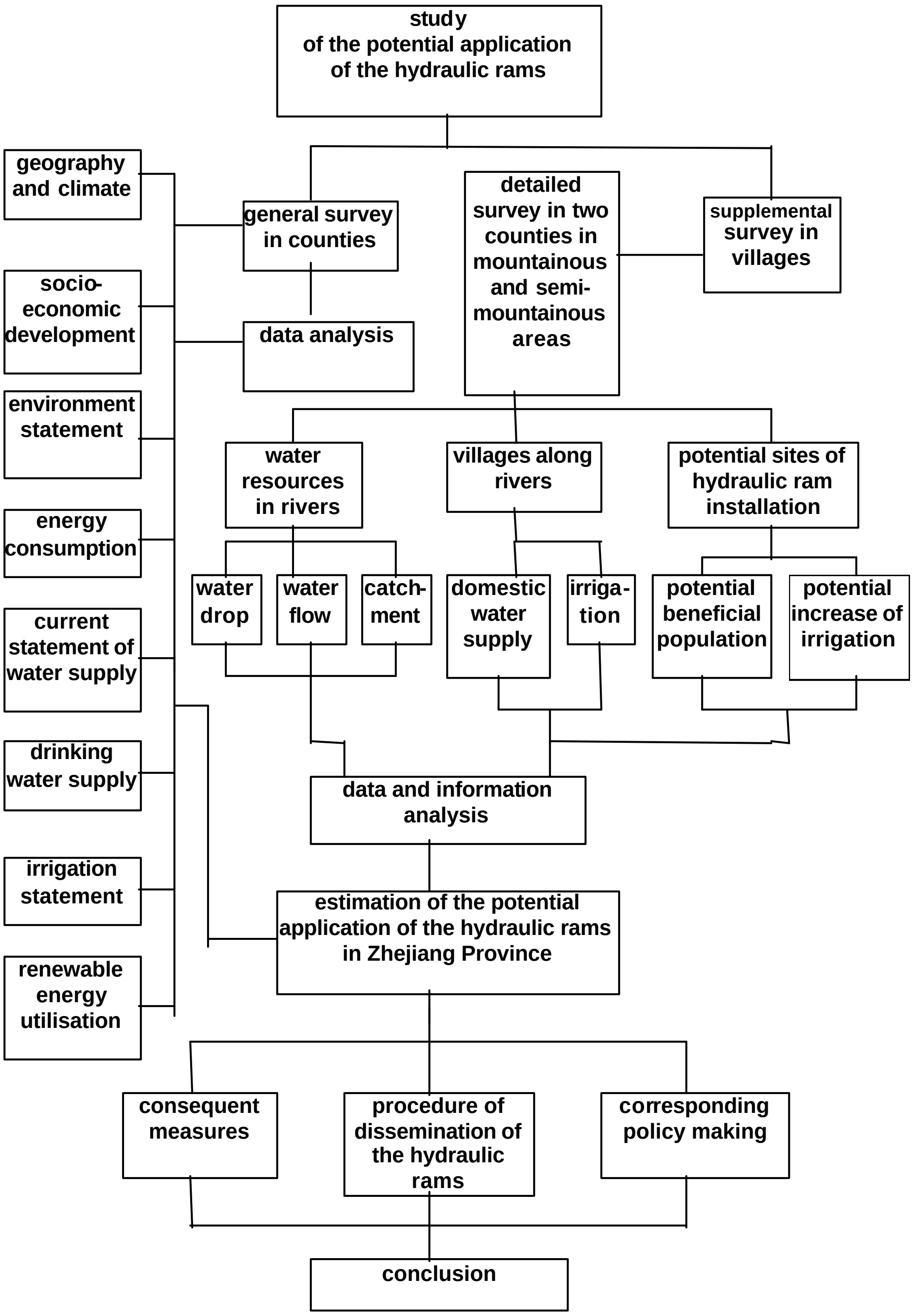


Fig. 1.7.6.1 Potential application of the hydraulic ram's study structure

The personnel dealing with the detailed survey was very experienced in hydraulic ram application, but to unify the definition of the potential for both counties it was necessary to decide what criteria the survey would use.

The number of potential sites for the installation of the hydraulic ram varied according to the different point of views. According to the farmers the number of potential sites are few because the hydraulic ram is not well-known and the farmers cannot afford all of the installation costs. However, the number of potential sites are actually much larger. The need for lifted water was unchallenged.

Farmers have requested installation of the hydraulic ram but in limited numbers. These numbers no longer represents the potential demand. The existing demand for hydraulic ram application has increased substantially

The potential sites are great, when taking the vast hydraulic resources into consideration Some sites are suitable for hydraulic ram installation, but there is no demand for lifted water because there are no villages or land needing irrigation. Therefore, taking the demand into account, the number of hydraulic ram needed is less than the potential.

The factors mentioned above were analysed with technicians and engineers from the two counties to make a unified definition of structure of the detailed survey. It was decided that the overall potential of the hydraulic ram should involve sites with hydraulic resources, independent of the present demand but taking into account future water lifting needs, whether for irrigation or domestic water supply.

On the basis of the general survey, the detailed survey, and the data analysis, technical and economic evaluation and comparison with other water lifting or pumping systems, the following can be concluded:

- The water supply systems for domestic use and irrigation are far from satisfactory, especially in Zhejiang’s mountainous and semi-mountainous areas.
- Zhejiang Province has rich hydraulic resources, which can be directly utilised for lifting water with an appropriate technology i.e. the hydraulic ram.
- Zhejiang’s mountainous and semi-mountainous areas have over 5500 sites suitable for the installation and operation of over 6000 sets of hydraulic rams.

- Compared with other water lifting or pumping systems, the hydraulic ram is the most appropriate device to be used in mountainous and semi-mountainous areas where there are hydraulic resources.
- The hydraulic ram can play an important role in a decentralised potable water supply system and irrigation because it is technically reliable, economically viable, easy to install and operate, and requires limited maintenance. It realises **China's Agenda 21**'s target for a sustainable rural development, conservation of natural resources, and environmental protection.

2 Function of the Hydraulic Ram

2.1 Description of the hydraulic ram

2.1.1 Water lifted by the hydraulic ram

In rural areas, there is great decentralised demand for water lifted for domestic supply and for irrigation purposes. When a water source is available, the hydraulic ram could be used for water lifting for both irrigation and domestic water supply without any consumption of conventional energies, such as electricity or diesel. Although the operation of the hydraulic ram doesn't need any conventional input, it still needs energy input, in form of potential energy contained in flowing water of small rivers or streams with natural water drop. This potential energy powers the hydraulic ram to lift water to a certain height. In certain cases, water could be lifted to over 100 metres. The applicable water drop, which could be in some cases artificially made, should be in the range of 1 – 7 metres.

The hydraulic ram could not be applied in case of pumping water from wells or water ponds, because in these cases, there is no potential energy available in the water to operate the hydraulic ram.

The output of the water lifted depends on the ratio of the water lift and the water drop (h/H), and the type and number of the hydraulic rams installed.

The hydraulic ram is only a part of a lifting system, which consists of a feeding tank (or water collection chamber), a feeding pipe, a fixing foundation, a delivery pipe, etc. as shown in Fig. 2.1.1.1.

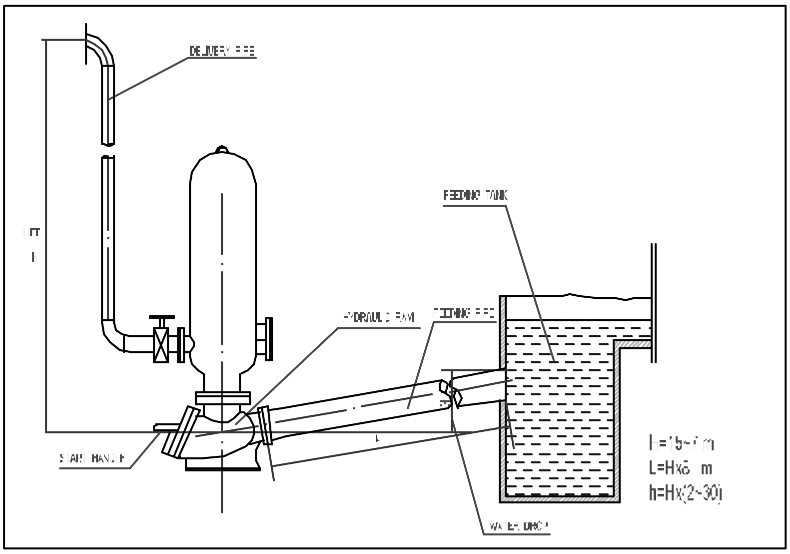


Fig. 2.1.1.1 Hydraulic ram system

2.1.2 Brief introduction of the history of the hydraulic ram development

The hydraulic ram operation is based on the ‘water hammering effect’ which was discovered and applied by a British (John Whitehurst, a member of Loyal Academy in Derby). In 1772, he produced the first set of the hydraulic ram applied in a brewery. At the time, this hydraulic ram could not operate automatically. Its valve had to be shut off manually to create the force of water hammering for water lifting. Therefore, he hired a boy to close the valve by hand to lift the water for the brewery.

The structure of that hydraulic ram was simple and workmanship skill was mediocre. It remained in operation till 1800. In 1775, John Whitehurst announced his innovation.

In 1776, the Frenchman Montgolfier, who was a paper dealer and also an innovator of the hot gas balloon, designed and produced a hydraulic ram based on the same principle. It was the first one operating automatically. It had already all important features of the structure of the hydraulic ram today. Montgolfier gave it the name ‘Le belier hydraulique’. Since then, this device was called ‘Hydraulic Ram’.

In 1796, Montgolfier got a patent for his design of the hydraulic ram in Paris. Till 1820, this patent was used in the Easton Company for the production. Based on the observation of the Montgolfier's hydraulic ram, a German, called Eytelwein, improved the design and made a comprehensive series of tests.

Since 1839, scientists in Europe had researched the water hammering phenomena appearing in the water pipes. In 1899, a Russian scientist was the first to put forward the theory of the water hammering, which was the theoretical basic for the development of the hydraulic rams.

From the 19^{th} century onwards, the development of the hydraulic rams went in two directions, i.e. the improvement of the mechanical design and the theory of operation principle. Universities in the United States, such as O'Brien and Gasline in California, or Lansford and Dugan in Illinois, conducted research and experiments on the hydraulic rams.

Only two moving valves are operating the hydraulic ram

In many other countries, people were interested in the hydraulic ram application and development. In the former Soviet Union, scientist and engineers did a lot in terms of structure improvement and theoretical researches on the hydraulic rams. In 1902, a set of the hydraulic ram was installed near Moscow. It was kept running properly till 1956, and beyond. In Romania, scientists also mad theoretical research work on the hydraulic ram.

In 1914, a Japanese made a trial design of the first set of the hydraulic ram in Japan. Afterwards, this design was greatly improved by many people, and finalised and put into production in 1954. In 50's, over 1000 sets of the hydraulic rams were installed and operated in Japan.

In the early 60's, based on the Japanese technology, engineers in Zhejiang, Jiangxi, Hunan and Guizhou Provinces had a trial production of the hydraulic rams and installed them for irrigation. Technically, this design had some shortcomings and the sites selected for the installation were not appropriate. Therefore, in the practical operation, there were problems, which could not be solved at that time. Due to technical and political problems, this trial was unsuccessful.

2.1.3 Water hammering effect and structure of the hydraulic ram

The hydraulic ram was designed to apply the water hammering effect to lift the water to a certain height. What is the water hammering effect? In one sentence: when flow is stopped suddenly, a high pressure will be created in the water, like a hammer hitting inside the pipe. This basic theory of water hammering taking place in the pipe was put forward by a Russian scientist, Prof. Jukowski, in 1899. Another Russian scientist, A. M. Wutlerow, made an experimental system to observe the water hammering in operating hydraulic rams. His experimental instrument was very simple, as shown in Fig. 2.1.3.1.

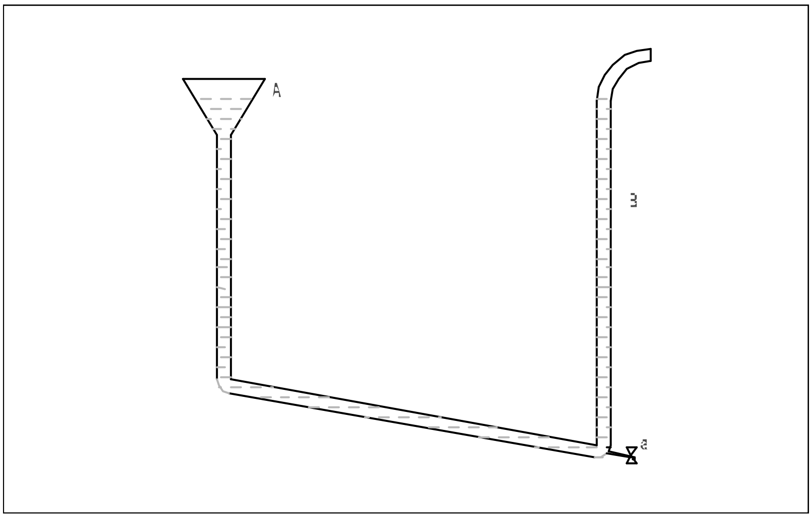


Fig. 2.1.3.1 experiment instrument of the water hammering effect

For the experiment, a piece of glass tube was needed, bent to the shape shown in Fig. 2.1.3.1 and having a small hole in the point a. The single steps of the experiment were as follows:

- Close the small hole with one finger;
- Pour the water into the glass tube until the water in point A and point B are at the same level;
- Remove the finger to allow the water to run out from hole a. The water flows starts;
- When the hole is closed suddenly, the water level in position A will become higher than position B until the water flows out of the tube.

The experiment described above is a simplified simulation of how the water hammering happens in the hydraulic ram system. The only difference between the experiment and the hydraulic ram operation is that in the experiment the water flow was stopped by hand, and in the hydraulic ram system the water flow is stopped by the discharging valve which close automatically by its own weight.

The hydraulic ram has simple structure, consisting of the ram body, air vessel, discharging valve and delivery valves which are the only moving parts in the hydraulic ram. These moving parts don’t need any lubrication and observation in the operation.

To start the operation of the hydraulic ram, the discharging valve is kept open with a handle; the water runs through the feeding pipe into the hydraulic ram and discharges from the discharging valve. The water flow starts and the velocity is increasing. As soon as the velocity reaches a certain point, the discharging valve will be suddenly closed by the kinetic pressure caused by the water flow hitting. The sudden stop of the water flow creates the water hammering to push the water at high speed through the delivery valve into the air vessel and compress the air in the air vessel. With the air pressure, a part of water is pressed through the delivery pipe to the height and the delivery valve is closed at the same time.

The high pressure in the chamber beneath the delivery valve, created through the water hammering, is released by pushing the water into the air vessel and by overcoming the resistance along the inside wall of the hydraulic ram, the delivery valve and the pipe. Due to the decrease in the inside pressure, the discharging valve opens automatically by its own weight. The water from the feeding tank (water resource with water drop) runs into the feeding pipe by gravity and a new cycle begins. Water is lifted by the water hammering effect and the cycle is continuously repeat .

2.1.4 Requirements of the hydraulic ram

The precondition for the operation of the hydraulic ram is the difference of water level, e.g. a water drop. Water in rivers or stream with a water drop is the carrier of potential energy. The potential energy in water is applied to lift water with the help of the hydraulic ram. It is a process of the transformation of the potential energy carried in the bigger amount of water with lower water drop, to the potential energy again but carried in the small amount of water with high water head. Therefore, in the hydraulic ram system, the working fluid to drive the hydraulic ram and the fluid to be lifted by the hydraulic ram are the same one, e.g. the water.

Between the two openings of the discharging valve, water flows inside the hydraulic ram and completes the cycle that effects the water lifting. The whole cycle consists of three steps.

■ **First step (see Fig. 2.1.4.1)**

Due to the opening of the discharging valve, the water flows from the feeding tank (water collection chamber) through the feeding pipe and runs out of the discharging valve with increasing velocity of the water flow. In this case, through the self-weight of the delivery valve and the pressure of water above, the delivery valves are kept closed.

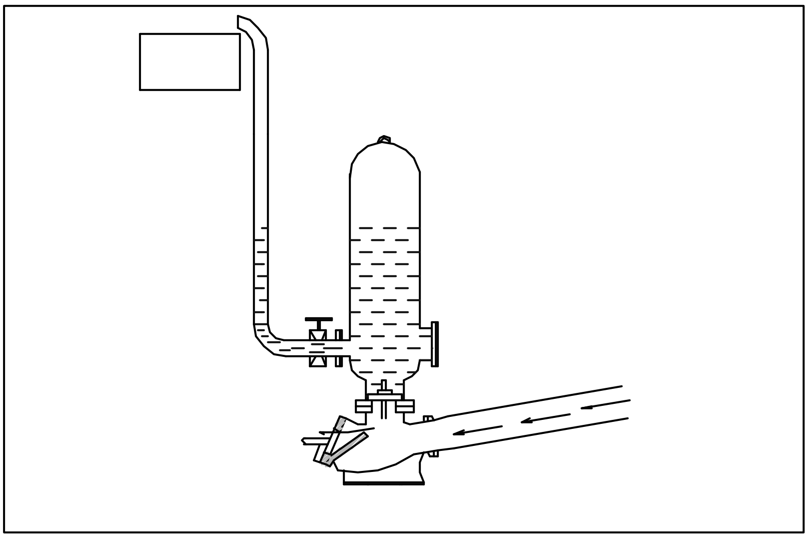


Fig. 2.1.4.1 first step of the hydraulic ram operation

■ **Second step (see Fig. 2.1.4.2)**

The water velocity reaches a certain point (the designed velocity), the discharging valve is quickly closed by the kinetic pressure caused by the water flow. Quick closing of the discharging valve stops the water flow suddenly. The so generated high pressure of the water pushes the delivery valve open. The high pressure of the water compresses the air in the air vessel and, at the same time, pushes a part of water into the delivery pipe.

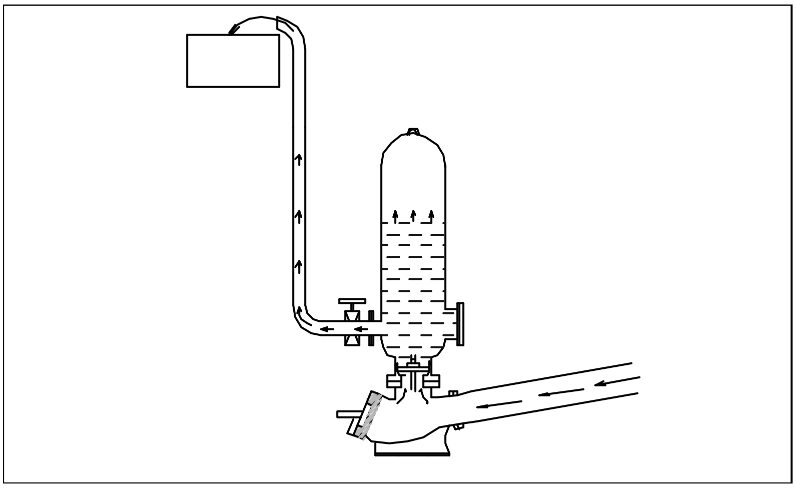


Fig. 2.1.4.2 second step of the hydraulic ram operation

■ **Third step (see Fig. 2.1.4.3)**

The compressed air expands and the delivery valve is closed once more while some water is pushed into the delivery pipe again. Overcoming the resistance in the pipes and valves, the water is lifted by the energy which is released through the water hammer when the high pressure drops. As the pressure under the delivery valve decreases the discharging valve is then opened by its own weight. With the opening of the discharging valve, the new cycle begins.

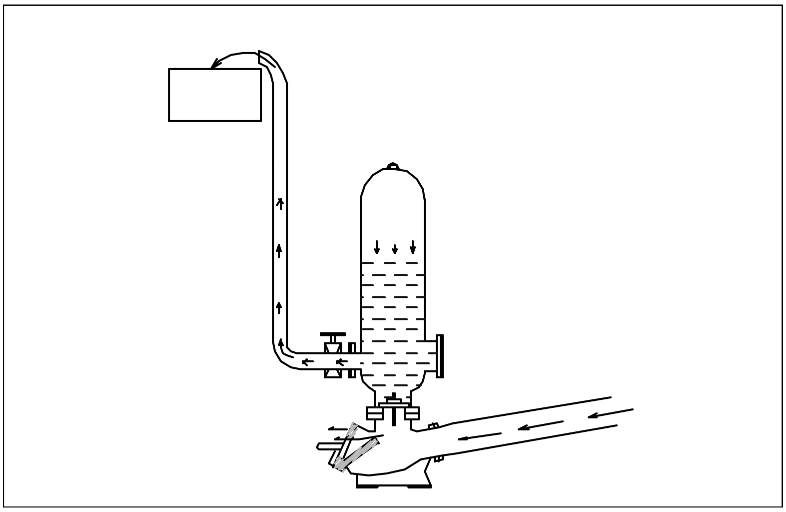


Fig. 2.1.4.3 third step of the hydraulic ram operation

2.2 Water source and water lifting

2.2.1 Water resource

What is a suitable water source, which could be applied for water lifting by the hydraulic ram? Simply in a word, a water drop (natural or artificially made) is a necessity. By this it is meant that a drop would cause water to flow from a higher level to a lower level by the gravity. Therefore, the fixing foundation to fix the hydraulic ram has to be lower than the level of the water source (water surface level in feeding tank or water collection chamber), and the level of the river or stream to discharge the water from the discharging valve should be lower than the fixing foundation. This is clearly explained in Fig. 2.2.1.1.

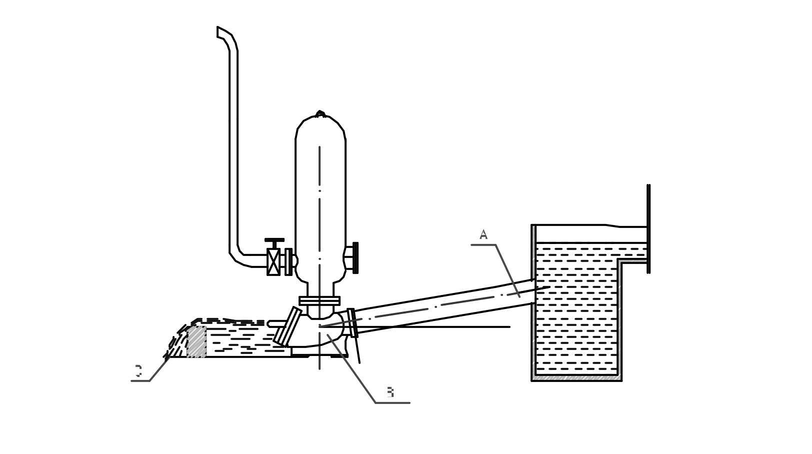


Fig. 2.2.1.1 level difference in the layout of hydraulic ram system

The water level A should be higher than the foundation fixing the hydraulic ram B, and the foundation B should be higher than the water level C of the river or stream to discharge the tail water from the hydraulic ram.

In some cases, where the water level A is not naturally high enough; a small dam to increase the water level of the water source is necessary. In the practical installation, it is suggested that the site selected for the hydraulic ram installation should have a water drop in range of 1 – 7 metres. When the water drop is less than 1 metre, the only way to use the hydraulic ram would be to artificially increase the water drop. There are two ways to increase the water drop:

- To raise the water level of the water resource by building a dam or increasing the height of the dam, to build a channel to guide the water from the rivers or streams; or
- To make the level of the foundation for fixing the hydraulic ram lower by digging if the tail water could not be discharged automatically.

Whatever is applied to increase the water drop, two question should be kept in mind:

- Is this additional investment affordable?
- Is it worth to put this investment in comparison to any other alternatives?

It is quite clear that the higher the water drop, the more the output of the water lifted. The comparison should be done between the additional investment for increasing the water drop and the additional output of the water lifted, e.g. to compare the marginal investment with the marginal benefit due to the additional output of the water lifted.

2.2.2 Rough quantity measurement of the water flow

The different types of the hydraulic rams make different demands on the quantity of water flow. For instance, BIL 840 needs much more water for its operation than BIL 420, and the mini hydraulic ram (Ladakh model) needs even less.

According to the practical experience in the hydraulic ram operation, the minimum water quantity of the water flow required by each type of the hydraulic ram are approximately as follows:

- 100 - 80 litres per second for BIL 840
- 50 – 40 litres per second for BIL 630
- 25 – 20 litres per second for BIL 420
- 10 – 5 litres per second for mini type

When the water flow is less than necessary, the hydraulic ram will not work. So it is necessary to identify the water quantity from the water source. There are several ways to measure the water flow roughly.

When possible, the easiest way is to guide the water flow through a water pipe or water trough into a bucket. The time to fill the water bucket and the water quantity in the bucket have to be measured. To make the measurement more accurate, the time and weight measurement could be repeated several times to get the average data.

In case there is no possibility to guide the water into a pipe, in order to get the data of the water flow, a water-discharging outlet should be made as shown in Fig. 2.2.2.1.

The width of the outlet could be in the range of 0.5 – 1 metre. The table 2.2.2.1 lists the water flow in the different depth of water flowing over the outlet. After the identification of the water flow, and considering the water demand, the type of the hydraulic ram could be decided.

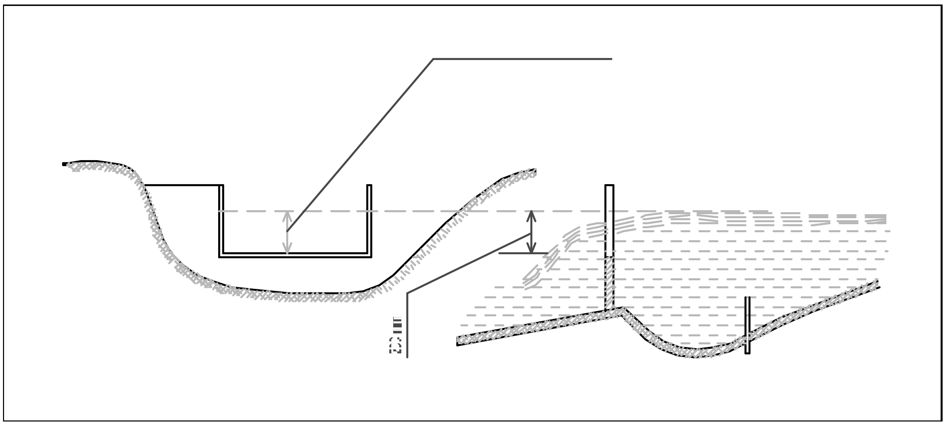


Fig. 2.2.2.1 water flow measurement

A hydraulic ram installed at a site in the mountain area

Table 2.2.2.1 water flow in different depth of water

Thickness of water overflowing (mm)	*Water flow (L/s)*	*Thickness of water overflowing (mm)*	*Water flow (L/s)*
10	1.7	240	202
20	5.8	245	207
30	9.7	250	212
40	15	255	220
50	20	260	226
55	23	265	233
60	26	270	239
65	30	275	245
70	32	280	253
75	36	285	259
80	40	290	266
85	43	295	273
90	47	300	280
95	51	305	287
100	56	310	293
105	60	315	301
110	64	320	309
115	68	325	315
120	72	330	323
125	77	335	330
130	82	340	338
135	86	345	345
140	92	350	353
145	97	355	360
150	101	360	368
155	107	365	375
160	111	370	382
165	117	375	392
170	121	380	399
175	127	385	408
180	132	390	415
185	138	395	423
190	143	400	431
200	154	405	439
205	160	410	447
210	166	415	455
215	171	420	463
220	176	425	472
225	182	450	514
230	188	480	567
235	194	500	603

2.2.3 Water quality

In nature, there is no purely clean water. When rain falls, it touches air, soil and any other materials. Water is no more pure. Although this kind of water is not pure and it could contain some mineral elements, it is not harmful to be used as drinking water. But in some cases water contains some harmful elements, which is not drinkable. Especially, river water and streams are polluted by the pollutants from wastewater, garbage disposal or by some production activities, such as pesticides sprayed against plant diseases or insects.

It is known that the hydraulic ram could lift water from rivers or streams with a water drop. The water in the rivers and streams is surface water, which can be easily polluted. When the site for the hydraulic ram water lifting system is selected, attention must be paid to the quality of water, especially the site for the in case of drinking water supply.

Before the decision is made for the site selection, the water quality must be tested. Although in China, people have a custom to drink the water boiled, the polluted water will contain some toxic elements which are very harmful for the people's health. If the site is selected for irrigation purposes, the problem of water quality will be of less important.

2.2.4 Natural drop and water lift

The water drop makes the water to flow through the feeding pipe, and the water flow make the hydraulic ram to operate. Therefore, it is a must that the water resource used for the hydraulic ram operation has a water drop in the range of 1 – 7 metres.

In the mountainous and semi-mountainous areas, small rivers or streams with a certain natural water drop can be found easily. But in some places, the natural water drop is not high enough to meet the lowest demand, for instance:

- Natural drop is less than 1 metre, which is the lowest for the hydraulic ram application;

- In the case that the natural drop is higher than 1 metre, but the required lift is high, the ratio of the lift to the drop is big, the output of the lifted water is less than the demand of lifted water;
- In the case the water demand is high, increasing the water drop could increase the water output, because increasing the water drop will reduce the ratio of lift to the drop, and then, more water can be lifted.

There are several ways to increase the water drop. Some simple ways are as follows:

- To build a dam or make the existing dam higher;
- To build a channel to guide the water from up reaches of the stream to the place for the hydraulic ram installation;
- Installation of a pipe connecting water from the up reaches to the place for the hydraulic ram installation, with the help of the siphon;
- To make the fixing foundation lower by digging only in the case the tail water could be discharged automatically.

In the case of building a dam or increasing the height of the existing, following points should be kept in mind:

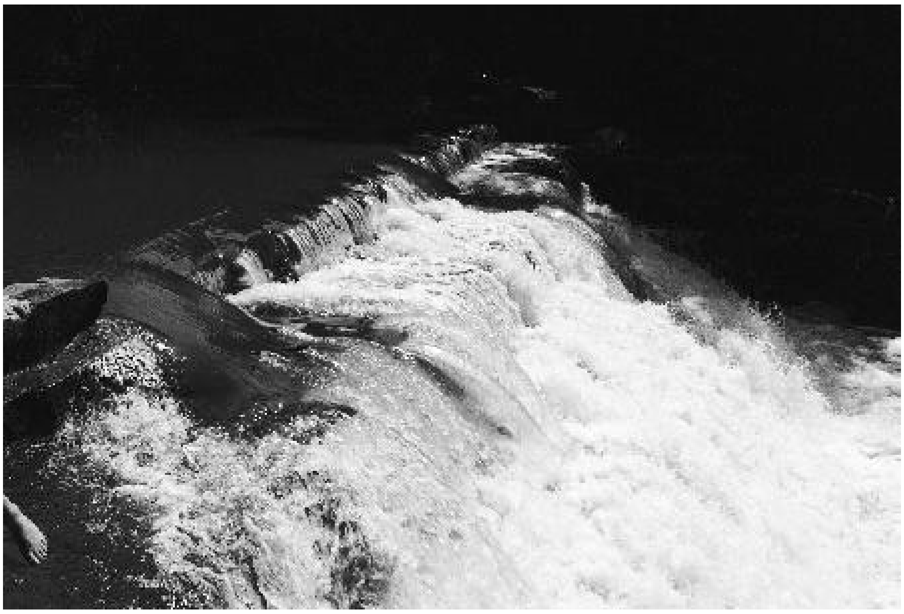
- The river or stream is not wide;
- The rise of the water level caused by the dam will not flood the land besides the rivers or streams in up reaches;
- In the raining season, the water could be easily discharged to avoid the flooding disaster.

When the natural slope of the river is limited, it will be no good idea to build a dam or to raise the dam’s height. It is necessary to build a channel to guide the water from up reaches. In this case, the following points should be put into the consideration:

- Size of the section of the channel, such as: 45x45, or 40x40, or 40x35 mm;
- Slope of the channel, such as 0.7%.

These are the basic data to design a channel. They are calculated from information, such as:

- Lifted water demand;
- Selected type of the hydraulic ram;
- Expected ratio of the lift to the drop;
- Water flow for the hydraulic ram operation.

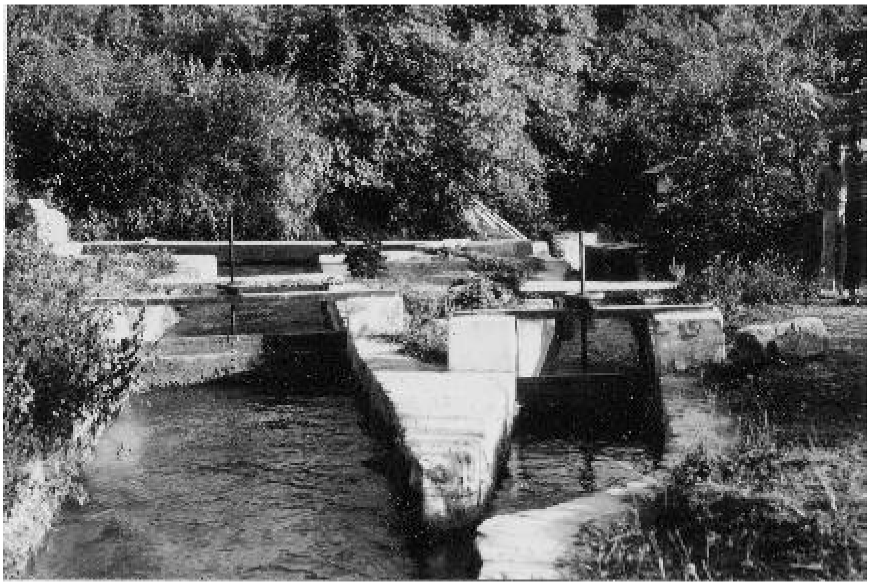


The natural drop of water

In construction of a channel to guide the water from up reaches, the slope of the channel is key parameter to get the expected water drop. But sometimes, it is difficult or it is very expensive to build a channel, due to the topographical conditions, then, a water guide pipeline could be taken into consideration. It is not necessary to install the pipe in a certain slope to keep the water. The water inside the pipeline can automatically flow with the water pressure on getting to the top. In the connection of the water pipe with the feeding tank, the water will rise, with the help of the siphon, to almost the same level as that in the up reaches of the rivers or streams.

The key parameter in this case is to select the right diameter of the pipe that can deliver sufficient water to operate the hydraulic ram. The diameter of the pipe is decided by the water flow needed for the type of the hydraulic ram selected and the ratio of the lift and the drop.

Whichever method is applied to increase the lift, it is necessary to make the analysis of the marginal cost, e.g. additional cost to increase the height of the water drop, comparing with the marginal benefit, e.g. the benefit gained by the additional water output, because maximisation of the water output is not the purpose of the optimisation of the hydraulic water lifting scheme. The purpose of the optimisation is to maximise the economic benefit.



An artifial drop is built

The concrete pipe with the proper connection could be a good recommendation for the pipeline installation.

The only way to maximise the output of the lifted water is to minimise the ratio of the lift to the drop. Therefore, the water lift should be as low as that it is just high enough to cover the necessary height for the water supply.

Since in the case the water drop is fixed, the higher the water lift is, the less water could be lifted. It means every metre of the water lift is realised by the loss of the lifted water quantity as the cost.

2.3 *Hydraulic ram production*

2.3.1 BIL type hydraulic rams

In the international co-operative project undertaken by the BORDA (Bremen Overseas Research and Development Association) co-financed by the German Government and the Commission of the European Union, the manufacturing technology of the hydraulic ram, including the software (completed set of the blueprints) and hardware (moulds for casting) were transferred free of charge to China.

Since the town Lishui is located in the heart of the area which is suitable for hydraulic ram application, two companies were selected there for the production.

Based on the manufacturing technology provided by BORDA, the Huaxia Company in Lishui produces 3 types of hydraulic rams, BIL 840, BIL 630 and BIL 420, principles and functions of which are similar.

The only differences between the types are:

- the water output in the same ratio of the lift to the drop, and
- the requested water flow to operate the hydraulic ram.

In case the ratio of the lift to the drop has the factor 10, the water drop is 2 m, the water should then be lifted to a height of 20 m. The efficiency of the water lifted for the different types is as follows:

l BIL 840, 250 – 300 m^3/ 24 hrs (day);
l BIL 630, 120 – 150 m^3/ 24 hrs (day);
l BIL 420, 60 – 80 m^3/ 24 hrs (day).

The main technical data for these three types are listed in Table 2.3.1.1

Table 2.3.1.1 main technical data of the different type of the hydraulic rams

Type	*Weight (kg)*	*Diameter of feeding pipe (mm/inch)*	*Diameter of delivery pipe (mm/inch)*	*Size (length x width x height)*
BIL 840	980	216/8	108/4	950x630x2200
BIL 630	578	159/6	80/3	520x420x2130
BIL 420	335	108/4	54/2	425x350x1840

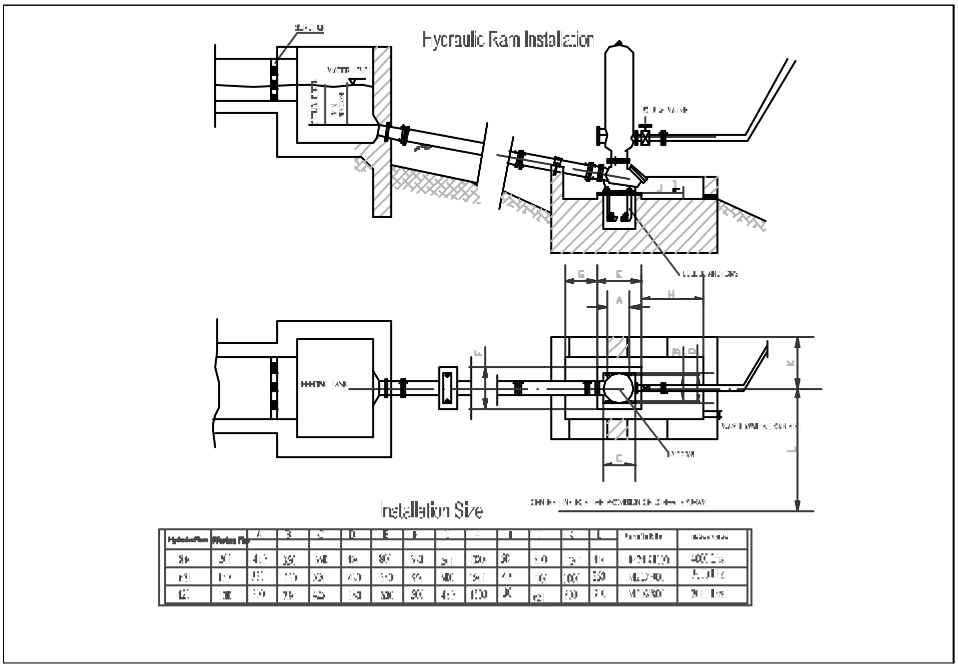
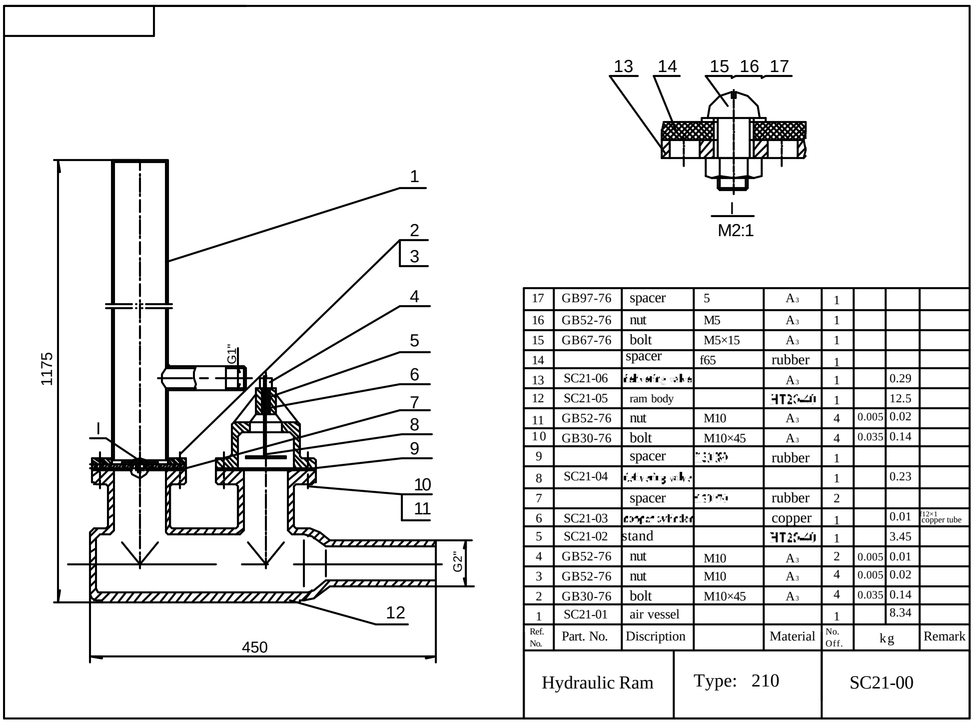


Fig. 2.3.1.1 principle drawing of BIL type hydraulic ram

2.3.2 Various other models of hydraulic ram and mini-type hydraulic ram

During the co-operation project of hydraulic energy utilisation in China and India, besides the manufacturing technology of BIL type provided by BORDA another type of the small hydraulic ram was transferred from the Ladakh area in India to Zhejiang Province in the P. R. of China. This type was originally manufactured out of pipe fittings. BORDA upgraded this model to a casted type, and INTECO in Delhi afterwards started production.

This type of the hydraulic ram is suitable for individual water supply for a few families in a village. Due to the limited capacity of the water lifting and the small size of the device, a mini type (Ladakh model) is used for this kind of production. The mini type works on the same principle, but its structure is different (see the principle drawing of the mini type in Fig. 2.3.2.1)



17	GB97-76	spacer	5	A_3	1			
16	GB52-76	nut	M5	A_3	1			
15	GB67-76	bolt	M5×15	A_3	1			
14		spacer	f65	rubber	1			
13	SC21-06	[illegible]		A_3	1		0.29	
12	SC21-05	ram body		[illegible]	1		12.5	
11	GB52-76	nut	M10	A_3	4	0.005	0.02	
10	GB30-76	bolt	M10×45	A_3	4	0.035	0.14	
9		spacer	[illegible]	rubber	1			
8	SC21-04	[illegible]			1		0.23	
7		spacer	[illegible]	rubber	2			
6	SC21-03	copper cylinder		copper	1		0.01	f12×1 copper tube
5	SC21-02	stand		[illegible]	1		3.45	
4	GB52-76	nut	M10	A_3	2	0.005	0.01	
3	GB52-76	nut	M10	A_3	4	0.005	0.02	
2	GB30-76	bolt	M10×45	A_3	4	0.035	0.14	
1	SC21-01	air vessel			1		8.34	
Ref. No.	Part. No.	Discription		Material	No. Off.	kg		Remark
Hydraulic Ram		Type: 210		SC21-00				

Fig. 2.3.2.1 principle drawing of the revised Ladakh type

The mini type has the water lifting capacity in the range of 1 – 2 m^3 within 24 hrs when the ratio of the lift to the drop (H/h) is 10. Its feeding pipe has the diameter of 2” and the delivery pipe has the diameter of 1”.

This type of the hydraulic ram is very popular in Ladakh in the Himalayan area of India. Due to the scattered locations of the farmer families in that area, similar to the Himalayan area in Tibet Autonomous Region and Qinhai Province in P. R. of China, the mini type just meets the individual family’s water demand due to the limited investment in the installation and less sensitive operation condition.

2.3.3 Selecting the type of hydraulic ram

The selection of the type of the hydraulic ram should be made with the consideration of following data and information:

- Lifted water demand and its tendency;
- Potential water users;
- Available water resource during the different seasons of the year of water management;
- Natural water drop;
- Possibilities of the water drop increase and their marginal costs;
- Necessary height of water lift.

The lifted water demand, its tendency and the potential water users could give a relatively comprehensive idea of the water demand, considering the local socio-economic development. The remaining information and the data are able to make the choice of the type and to show how much water could be lifted.

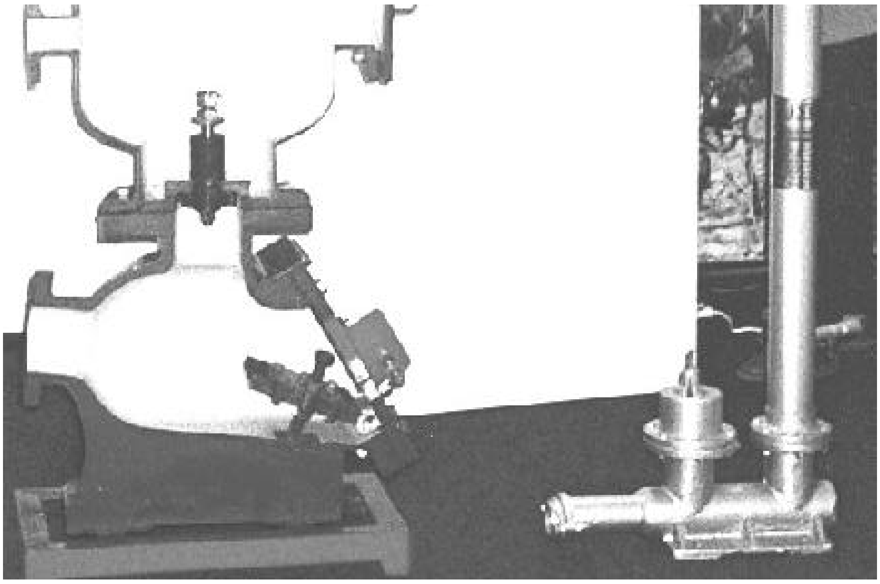
When the water resource is limited, water flow is the key parameter to choose the type, then the compromise between the water supply and demand becomes necessary. When the water resource is abundant, the lifted water demand becomes a key parameter to select the suitable type and number of the hydraulic ram installed.

The hydraulic rams (in different types or same types) could be installed in parallel as per priciple drawing in Fig. 2.4.9.1. The more sets of the hydraulic rams are installed, the more water could be lifted. In this case, the water demand changed due to the rising living standard and the increasing population. Also the growing potential of water use for irrigation of fruit trees, vegetables, mushrooms, etc. should be taken into account.

2.3.4 Water lifted

The water quantity lifted is mainly depending on (H/h) the ratio of the water lift to the drop. The smaller the ratio is, the more of water could be lifted.

The mini-hydraulic ram



The different size of the mini-hydraulic ram and the BIL 420 family type is obvious.

Although it is difficult to get the exact water output due to the different ratio (H/h), resistance of water head loss, operation frequency adjustment and the water level in the feeding tank and water level in the discharging pond etc., theoretically there is a formula available to calculate the lifted water output:

$$q = h \cdot h \cdot Q/H$$

Where:

q: quantity of water lifted (litre/second)

Q: water flow into hydraulic ram (litre/sec.)

h: water drop of water resource (metre)

h : efficiency of hydraulic ram itself

H: water lift, (metre)

According to the data got from the laboratory experience, the efficiency of the hydraulic ram with 100 mm of the feeding pipe's diameter, varies with the H/h ratio, which is shown in the curve in Fig. 2.3.4.1, (source: 'Die Pumpe', 1963).

Some similar experiments for getting the water lifting efficiency of the hydraulic ram with 100 mm feeding pipe were done. The main data are shown in Fig. 2.3.4.2, Fig. 2.3.4.3 and Fig. 2.3.4.4, (source: 'Hydraulic Ram Experiment', Wang Rongdu, 1964)

Water is lifted to quite high situated fields

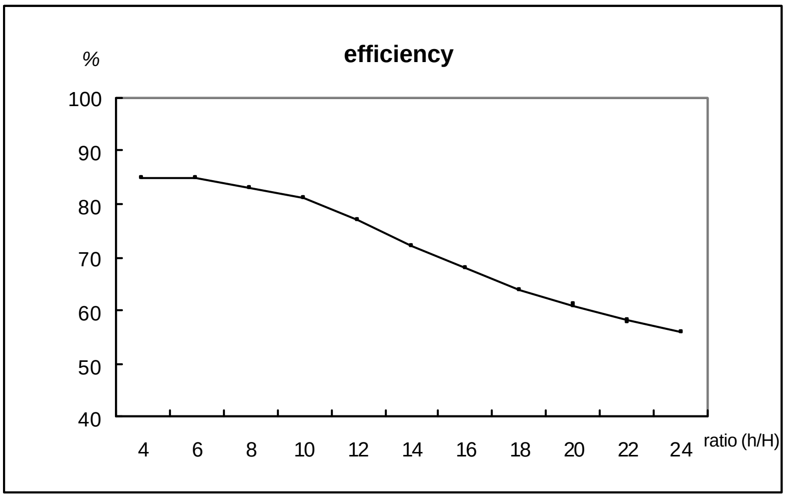


Fig. 2.3.4.1 efficiency curve of hydraulic ram with 4' feeding pipe

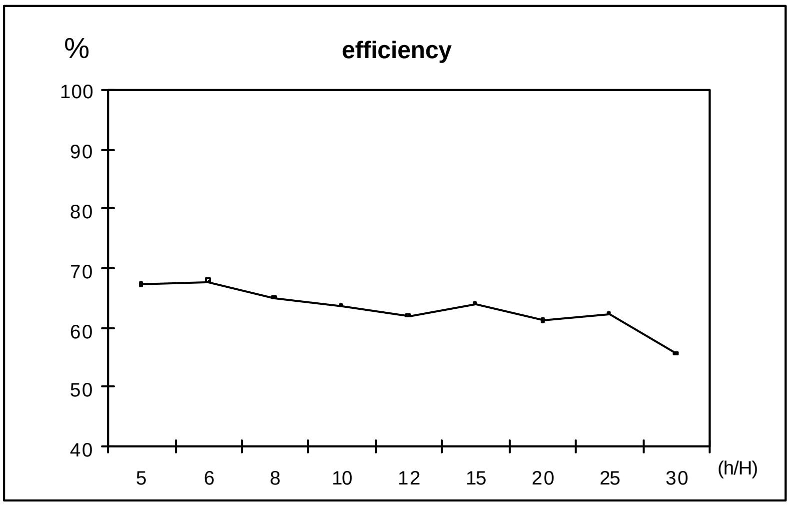


Fig. 2.3.4.2 water lifting efficiency in the condition of 1 metre of drop and working frequency of 29 per minute

Fig. 2.3.4.3   water lifting efficiency in the condition of 1.6 metres of drop and working frequency of 20 per minute

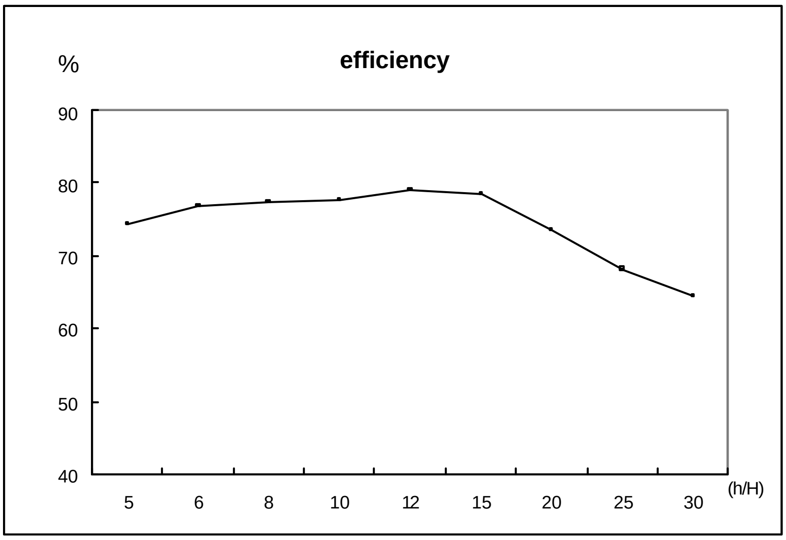


Fig. 2.3.4.4   water lifting efficiency in the condition of 3 metres of drop and working frequency of 24 per minute

In field practice, the water output will be less than the calculated q, because of the water head loss due to the resistance in the system. Therefore, the revised formula is:

$q = h \cdot h \cdot Q/(H+H_1)$

Where:

H_1: water head loss due to the resistance.

The lifted water quantity q of the different types of hydraulic ram in the various ratio of h/H is shown in Table 1.

The resistance depends on the resistance in the bends and elbows, and on the consistency of the inside wall of delivery pipe. It will be further discussed as a special topic in this chapter.

Table 1 relation between lifted water quantity and ratio (h/H) for reference

Unit: litre/minute

Type / ***Ratio (h/H)***	***BIL840***	***BIL630***	***BIL420***
2	423	325	175
4	365	216	84
6	305	171	64
8	260	144	51
10	219	124	43
12	193	111	36
14	180	99	33
16	157	90	27
18	144	81	25
20	133	75	21
22	125	67	20
24	116	63	19
26	108	57	16
28	98	51	15
30	90	49	13

In the practice, the lifted water output from the hydraulic ram scheme will be less than the data shown in the above table 1, because the head loss of the delivery pipe is not taken in account due to the differences from place to place.

The mini type of the hydraulic ram (Ladakh model) is more flexible in the installation. In principle, the ratio of the length of water drop to the feeding pipe should be 1:8. But in the practice, when the ratio is in the range of 1:4 – 1:8, the scheme still could work. Some experimental data shows the relationship between the ratio (h/H), water output in the different ratio of the water drop to the length of the feeding pipe. All these data are listed in Table 2.

In the practical installation, the water output of the mini type will be also less because the scheme's water head loss could not be taken into account due to the different delivery pipes from place to place.

Table 2 experiment data for the mini type (Ladakh model)

Water drop (metre)	**Lift (metre)**	**Length of feeding pipe (metre)**	**Water output (Litre/hour)**
1.00	10	8.00	168
1.00	8	8.00	285
1.00	6	8.00	411
1.14	10	8.00	392
1.14	8	8.00	426
1.14	6	8.00	480
1.00	10	6.00	198
1.00	8	6.00	294
1.00	6	6.00	552
1.14	10	6.00	402
1.14	8	6.00	432
1.14	6	6.00	528

2.4 Hydraulic ram installation

2.4.1 Site selection

Site selection is the most important condition for the hydraulic ram installation and operation. If the site selected is a suitable one, over 50% of the success has been already gained. It is necessary to understand if there is a possibility for the hydraulic ram operation and what is suitable for the site. The possibility means that it is possible to install the hydraulic ram and operate it, e.g. there is water drop available. But possibility does not mean suitability because suitability requires more:

- What kind of water flow, river, stream, or the water released from reservoir, etc.
- Water quality of the resource
- Water demand, including the estimated potential demand
- Necessary height of the lift
- Distance from the installation site to the water users
- Change of the water flow in dry season and raining season
- Any possibility of the pollutant discharged to the water resource in up reaches
- How to raise the additional water drop, if the water drop is not high enough
- Possibility to store the lifted water
- How high is the investment for the system
- What is the estimated potential benefit

After all these questions are identified, and the answers sound positive, this site could surely be a suitable site, otherwise, some more comparisons with other alternative should be made for the final decision. These comparisons should cover the aspects of :

- Technical reliability
- Investment and running costs, e.g. economic situation of the farmers
- Operation, maintenance and necessary repairs, etc.

2.4.2 Layout design of the system

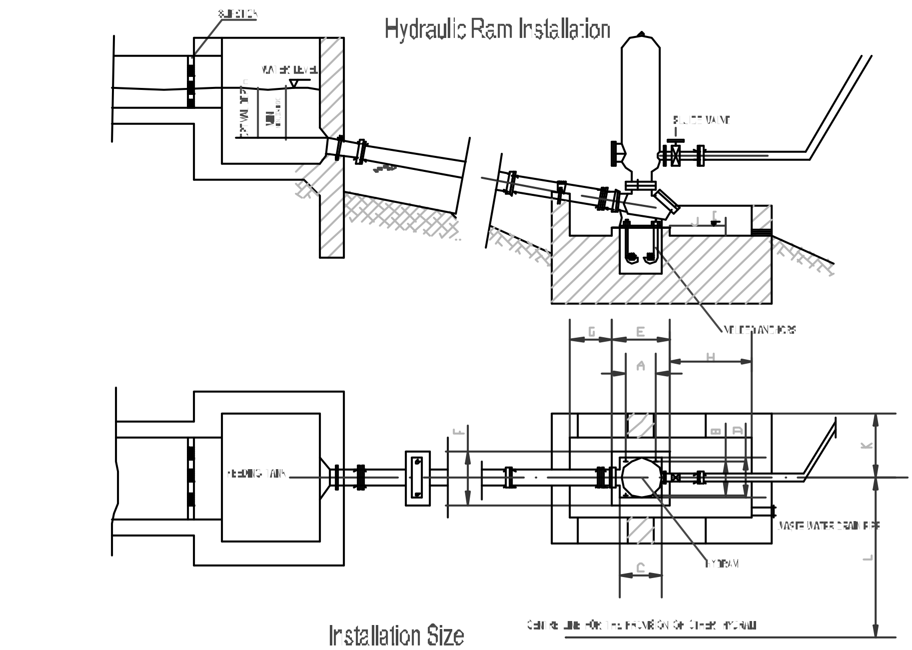
While the site for the hydraulic ram installation is selected, the design of the system layout becomes the next important step. A good design should take into account of the local topographical condition and existing facilities, which are possibly integrated into the hydraulic ram system.

Since the topographical condition and local existing facilities are different from place to place, there is no standard layout available to guide the design. But the most important principle for the layout design is:

- to minimise the investment in construction
- to maximise the natural water drop as far as possible by using the natural slope
- to use as much as possible the existing facilities, such as, existing channel to guide the water flow, existing pipeline used for the irrigation system, existing water tank or water pond for the lifted water storage, etc.

A good design can save considerable investment cost in certain cases, and the output of the water lifted can be considerably increased with the help of a clever layout design.

Fig. 2.4.2.1 shows the principle drawing of the hydraulic ram installation.



Installation Size

Hydraulic Ram	ΦFeeding Pipe	A	B	C	D	E	F	G	H	I	J	K	L	[illegible]	Minimum volume
840	200	460	350	650	480	800	850	500	2000	50	500	1200	410	M24X1000	4000 Ltrs.
550	150	350	200	520	420	650	550	500	1800	40	700	1000	350	M20X950	3000 Ltrs.
450	100	310	250	425	350	600	500	450	1600	30	650	800	310	M20X850	2000 Ltrs.

Fig. 2.4.2.1 the principle of the layout for the hydraulic ram installation

The hydraulic ram is fixed in a small pond

After the layout design is done, the detailed design should be made, which includes:

- Feeding tank or water collection chamber, including the water guide facilities, such as, channel or siphon pipeline;
- Feeding pipe to create the water flow entering the hydraulic ram;
- Foundation fixing for the hydraulic ram;
- Discharging pond, including the outlet for water overflowing;
- Delivery pipeline, including the valves, bends or elbow necessary;
- Water storage, water distribution pipeline or channel for the water users or other irrigation techniques like sprinklers or drop irrigation.

2.4.3 Feeding tank (collection chamber)

The functions of the feeding tank are:

- To guide the water to the feeding pipe;

- To adjust the water quantity in short time and to keep the necessary height of the water level above the inlet of the feeding pipe;
- To filter the grass, plants, garbage and sediments to the feeding pipe and the hydraulic ram;
- To stop the water entering the system while the system needs maintenance.

A very important point is to keep the water level above the inlet of the feeding pipe over 30 cm and keep the distance between the inlet of the feeding pipe and the bottom of the feeding tank also over 45 cm. If the natural structure of the stream has a water collection chamber which has the same functions of the feeding tank, the feeding tank might not be necessary in this case. A grid is always necessary to collect the garbage from the water to avoid disturbance during the operation of the system.

2.4.4 Feeding pipe

The composition of the feeding pipe, which is connected between the water resource in the feeding tank and the hydraulic ram to guide the water flow into the hydraulic ram, is an important factor for the system.

The length of the feeding pipe is 8 times as the water drop. It means, when water drop used for the water lifting system is 2 metres, the length of feeding pipe should be 16 metres. In the same way, when the water drop is 3 metres applied in the system, the feeding pipe has to be 24 metres. In this way, it keeps the right installation angle of 7 degrees for the feeding pipe, which is an empirical size.

In other words, the technical requirement for the feeding pipe installation is to keep the angle between the horizontal and feeding pipe in 7 degree, because the type BIL hydraulic ram is designed to operate in this angle and the flange connecting the feeding pipe with the hydraulic ram is designed in the same angle. While the angle is bigger or smaller than 7 degree, the hydraulic ram fails to operate. Moreover, the feeding pipe should be installed straight.

In order to facilitate maintenance, there is a valve installed in the feeding pipe to shut the water flow when necessary. This valve is not a must, but a recommendation. To save initial investment cost, it is not installed in the system in most of the cases, as the field experience shows, because valves having a diameter of 8’, 6’ and 4’ are quite expensive.

It is suggested that seamless steel pipes should be used as feeding pipe, because its pressure and vibrate-resistant. It is not recommended to select the iron casting pipe as well as the concrete pipe. Farmers sometimes like to use second hand pipes to reduce their investment.

2.4.5 Fixing foundation and installation of the hydraulic ram

In operation, the hydraulic ram should be tightly fixed against the strong vibration due to the high pressure caused by the water hammering. At the bottom of the hydraulic ram, there are 4 holes for the fixing bolts, which are tightly casted into the concrete foundation. With the help of these 4 bottom bolts and nuts, the hydraulic is installed on the foundation. The foundation should be strong enough to overcome the vibration. Stability and firmness of the foundation have to be made sure before fixing the foundation bolts firmly.

Some points should be kept in mind:

- The right grade of cement in the concrete
- The maintenance period for the concrete
- The depth of the foundation bolts inserting into the foundation
- Horizontal of the foundation

The cement used for the concrete foundation should be higher than B 35 grade of the cement, and the time for the concrete maintenance should be at least 28 days. The bolts inserted in the foundation should have a depth of 85 cm for 840 type, 71 cm for 630 type and 420 type, to make sure that the they are strong enough to withstand the vibration caused by the hydraulic ram operation.

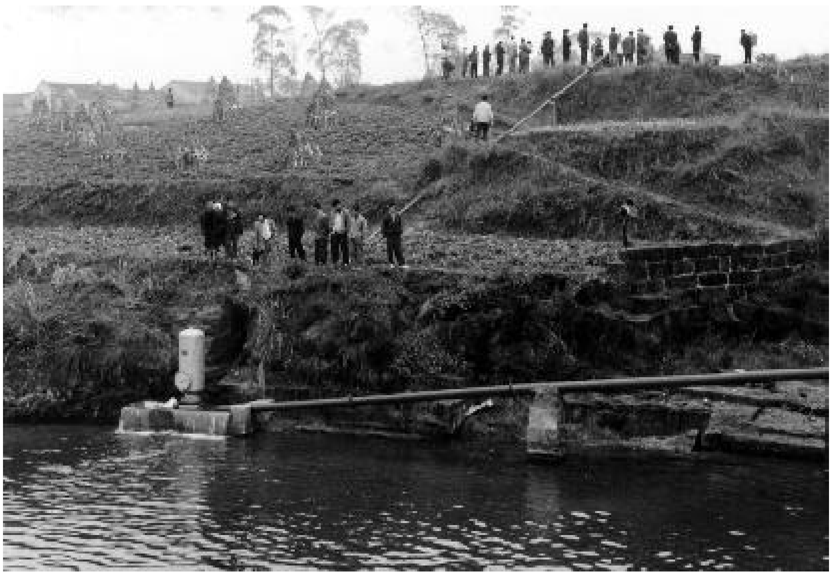
2.4.6 Discharging pond

The discharging pond has two functions:

- Keep the discharging water level covering the discharging valve
- Create the backflow, allowing an easy opening of the discharging valve

According to the standard of the hydraulic ram installation, the discharging pond should keep the discharging water high enough to just cover the upper edge of the discharging valve. In this case, some air necessary could come into the air vessel.

When the water level is too high, no air is coming through the discharging valve into the air vessel. When water level is too low, too much air will come into the air vessel. According to the design of the hydraulic ram, these two cases will disturb the proper operation efficiency of the hydraulic ram. Although the type of BIL hydraulic ram is not sensitive for the water level of the discharging pond, it can operate even when the water covers whole lower portion of the air vessel or when there is completely no water covering the hydraulic ram in the case the discharging pond is not built, the right water level in the discharging pond should be kept for two reasons:



This photo shows the complete system

- Efficient output of the water lifted
- Stable operation for the hydraulic ram system

The size of the discharging pond is not strictly standardised, but the distance between the hydraulic ram and the inside wall opposite to the discharging valve should follow the standard designs:

- for type BIL 840, 2 metres
- for type BIL 630, 1.6 metres
- for type BIL 420, 1.4 metres

The right distance will create a backflow from the inside wall of the discharging pond which helps to open the discharging valve. The standardised design of the discharging pond could also help to operate the hydraulic ram system in an efficient way and keeps the operation of the system stable. The pond should have a gate to drain off the water for maintenance and frost protection in winter.

2.4.7 Delivery pipe

The delivery pipe is a part of the system to deliver the lifted water to the expected height.

The installation of the delivery pipe should follow the principles:

- Minimise the resistance in the pipeline
- Minimise the cost of the delivery pipe

Using as many bends as possible instead of elbows, and using the bends of obtuse angle instead of right angle or acute angle, could reduce the resistance inside the delivery pipe. The layout of the delivery pipe should be designed in a way keeping the slope continuously high until reaching the water storage. When the delivery pipe is installed up and down, the air will stay inside the pipe, which will increase the resistance. Every resistance will lead to a water head loss and reduce the output of the water lifted.

For minimising the cost of the delivery pipe, there are several ways to be recommended. When it is possible to install the delivery pipe underground, the PVC pipe could be used instead of steel pipe. When the delivery pipe is long, the diameter of the pipeline could be smoothly reduced. For instance, when type BIL 630 is installed, the delivery pipe should be a pipe with 3' of the diameter. But after 20 – 30 metres of 3' diameter pipe, a pipe with diameter of 2.5' or 2' could be connected with reducing joint. In the same way, the pipe with diameter of 1.5' could be connected further on according to the lifted water output.

In the cases when 2 or 3 or even more sets of the hydraulic rams are installed parallel, the delivery pipes for every set could be merged one after the other into one delivery pipeline, after approx. 10 metres of the individual pipelines.

The water head loss is mainly caused by the friction between the water and the inside wall of the delivery pipe. The longer the delivery pipes and the higher the velocity of the water inside the pipe is, the greater is the water head loss. This water head loss could be calculated according to the data in Table 2.4.7.1.

Table 2.4.7.1 water head loss in every 100 metre pipeline

Water lifted		*Diameter (mm)*			
L/s	*M^3/d*	*25*	*50*	*70*	*80*
0.070	6.000	0.250	0.0063	0.0016	0.00055
0.075	6.500	0.290	0.0073	0.0018	0.00063
0.080	6.900	0.340	0.0082	0.0020	0.00072
0.085	7.300	0.380	0.0093	0.0023	0.00081
0.090	7.800	0.420	0.0100	0.0026	0.00091
0.095	8.200	0.470	0.0120	0.0029	0.0010
0.100	8.600	0.520	0.0130	0.0032	0.0011
0.110	9.500	0.630	0.0160	0.0039	0.0013
0.120	10.400	0.750	0.0190	0.0046	0.0016
0.130	11.200	0.880	0.0220	0.0054	0.0019
0.140	12.100	1.020	0.0250	0.0062	0.0022
0.150	13.000	1.170	0.0290	0.0072	0.0025
0.160	13.800	1.330	0.0330	0.0082	0.0029
0.170	14.700	1.490	0.0380	0.0092	0.0032
0.180	15.500	1.680	0.0420	0.0100	0.0036
0.190	16.400	1.870	0.0460	0.0120	0.0040
0.200	17.300	2.070	0.0520	0.0130	0.0045
0.250	21.600	3.240	0.0810	0.0200	0.0070
0.300	26.000	4.660	0.1200	0.0290	0.0100
0.350	30.000	6.350	0.1600	0.0390	0.0140
0.400	34.560	8.290	0.2000	0.0510	0.0180
0.450	38.880	10.50	0.2600	0.0640	0.0220
0.500	43.200	12.90	0.3200	0.0790	0.0280
0.600	51.840	18.60	0.4600	0.1150	0.0400
0.700	60.480	25.40	0.6300	0.1500	0.0550
0.800	69.120	33.20	0.8200	0.2000	0.0700
0.900	77.760	42.00	1.0400	0.2600	0.0900
1.000	86.400	51.80	1.2900	0.3200	0.1100
1.500	129.60	116.60	2.9000	0.7200	0.2500
1.600	138.24	132.50	3.2900	0.8100	0.2800
1.700	146.88	149.70	3.7200	0.9200	0.3200
1.800	155.52	-	4.1700	1.0300	0.3600
1.900	164.16	-	4.4600	1.1500	0.4000
2.000	172.80	-	5.6800	1.4000	0.4900

2.4.8 Water storage

In the hydraulic ram system, the water storage is not absolutely needed, but it will be better if a water tank could be built for storing the lifted water.

To meet the demand of water, in many cases, the water storage is necessary, because the instantaneous water demand might exceed the quantity of possible water lifting. The hydraulic ram could lift the water for about 24 hours without pause. The water storage will be functioning as a reservoir to meet the big amount of the water demand in a short time.

If it is possible to integrate the system into an existing water pond or water tank, the initial cost, especially the labour cost, will be considerably reduced.

If a new water tank is to be built, the following should be taken into account to decide on the necessary volume and on the way of water management:

- When does the highest water demand happen? For what period of time?
- What is the demanded quantity of water and how does it change during 24 hours?
- What is the water quantity lifted within 24 hours?
- What is the easiest way to make water management most efficient?

2.4.9 Hydraulic ram installed in parallel and in series

Several sets of the hydraulic rams could be installed in parallel or series according to the local condition. In the case, the water resource is rich and water demand is high, single set of the hydraulic ram could not lift the sufficient water to meet the demand, it is recommended to install several sets of hydraulic rams parallel in a range. In principle, the number of hydraulic rams installed in parallel is not limited. The layout design of the parallel installation is shown in Fig. 2.4.9.1.

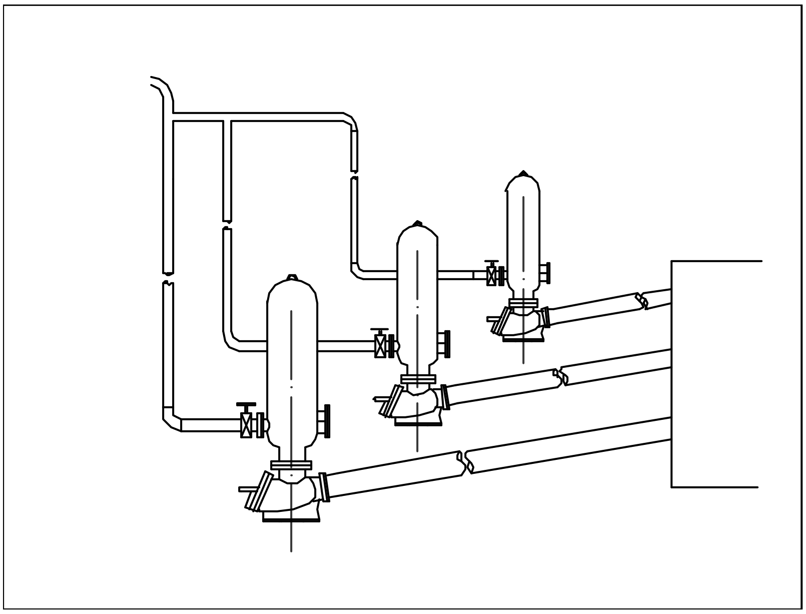


Fig. 2.4.9.1 Parallel installation of the hydraulic rams

In case, the single set of the hydraulic ram could not meet the demand, but the water resource is abundant, it is recommended to install two or three sets in series.

On principle, it should be kept in mind that the type of hydraulic ram installed in the second step should be one type smaller than that of the hydraulic ram installed in the first step. For instance, in case three sets of hydraulic rams are to be installed, in the first step, a set of 840 type should be installed, then a set of 630 type in the second step and a set of 420 type in the last step (e.g. third step in this case). Fig. 2.4.9.2 shows the layout design of the serial installation of two sets of hydraulic ram, as an example. The tailwater of the bigger one is the source for the smaller one.

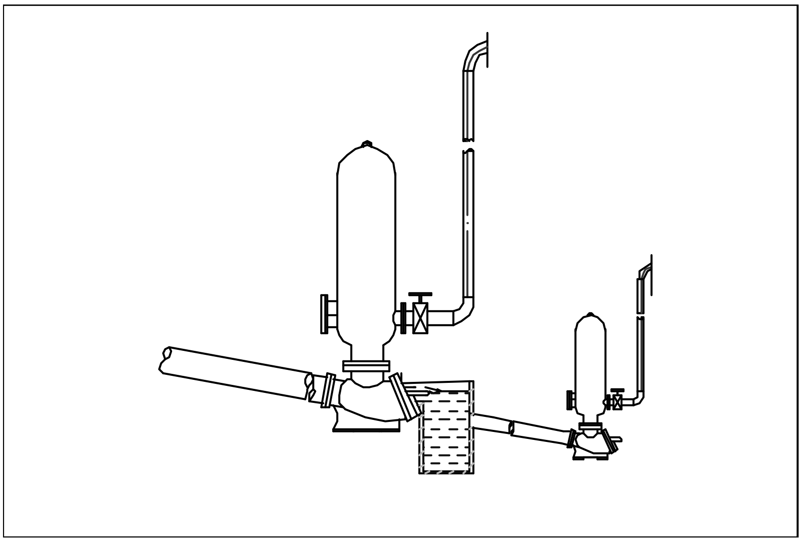


Fig. 2.4.9.2 serial installation of two sets of the hydraulic ram

A number of 8 hydraulic rams installed in series in the Indian mountain area of Dehradun

2.5 *Hydraulic ram operation and maintenance*

2.5.1 Operation

After a water lifting scheme with the help of the hydraulic ram is installed, the operation of the system become possible. Before starting operation, it is necessary to check the water level above the feeding pipe. The water level should be higher than 30 cm, otherwise, the air will flow with the water into the hydraulic ram, and the output of the water lifted will be obviously reduced, or the operation will even be disturbed and the hydraulic ram fails to work (see Fig. 2.5.1.1).

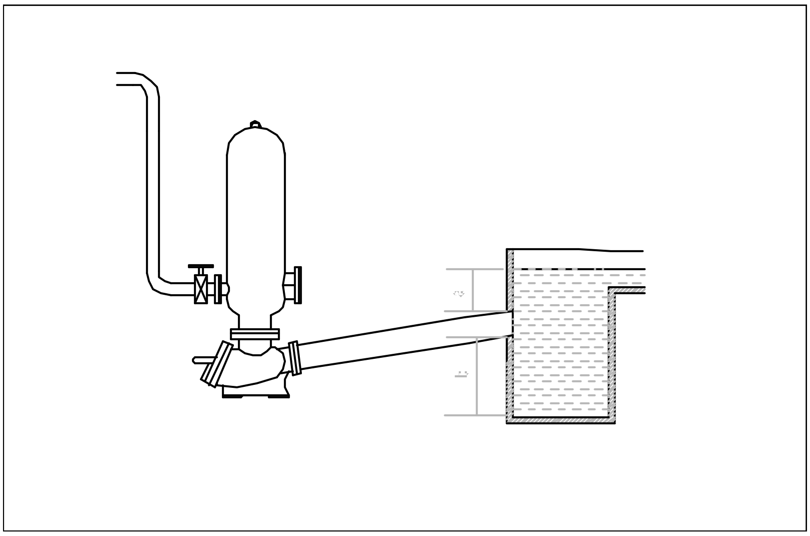


Fig. 2.5.1.1. feeding pipe's inlet position

The inlet of the feeding pipe is more than 30 cm below the water surface and should have a distance of at least 45 cm to the bottom of the feeding tank to avoid that sediments are flowing with the water into the hydraulic ram because stones, sand or sediments will disturb operation. It is easy to start the operation of the hydraulic rams. With the help of a handle, the discharging valve is opened. Then keep the valve opened for a few seconds and take the handle away from the valve, the valve will be automatically closed and the operation starts.

In the centre of the discharging valve, there is an adjustment screw, which could be used to adjust the operation frequency of the hydraulic ram. The times of opening and closing of the discharging valve in a certain period, for instance in a minute, mean the operation frequency of the system, which should preferably be in a range of 12 – 35 times per minute according to the ratio (h/H) of the lift to the water drop. According to field experiences, the optimum is 24 time per minute.

When the adjustment screw is turned clockwise, the operation frequency will be faster, vice versa; the operation frequency will be slower. It is not true that the faster the operation frequency is, the more water could be lifted. In the certain ratio (h/H), there is an optimal frequency. There is no theory available to give the optimal frequency. It could only be found out in the practical operation. The steps to adjust the screw to get the optimal frequency are as follows:

- First step: Start the operation with a lower frequency, for instance, 18 times per minute and measure the lifted water quantity;
- Second step: Turn the screw 360^o clockwise and measure the frequency and the water output;
- Thirds step: Repeat the second step, make the measurement, and write down the frequency and the water output. Make the data comparison between the water output with the increase of the frequency;
- Fourth step: Stop turning the screw for increasing the frequency when no increase of water output is found through increase of the frequency;
- Fifth step: Fix the adjustment screw with the counternut outside the discharging valve, because the position of the adjustment screw is in a position to have an optimal frequency.

There are three examples to explain the procedure of the frequency adjustment to maximise the water output. The optimal operation frequency of the hydraulic ram varies according to the different water drops, lifting height and the types of the hydraulic rams. Some experience was gained to find the optimal operation frequency for different types of the hydraulic ram in the practical operations, shown in Table 2.5.1.1, 2.5.1.2 and 2.5.1.3.

Table 2.5.1.1 - Table 2.5.1.2 - Table 2.5.1.3

Frequency (time/min.)	*Test time (second)*	*Lifted water quantity (kg)*	*Average quantity of water lifted (kg)*	*Average water lifted per day (m^3/day)*
Table 2.5.1.1 experiment data for type 630 in water drop of 3 m and lifting height of 25 m				
23	300	307.5	1.025	88.56
16	217	307.5	1.417	122.433
13-14	195	307.5	1.577	136.246
11	325	307.5	0.946	81.747
Table 2.5.1.2 experiment data for type 420 in water drop of 5.5 m and lifting height of 63 m				
26	484	112.6	0.233	20.1
20	355	112.6	0.317	27.4
16	292	109.2	0.374	32.3
14	314	133.25	0.424	36.7
Table 2.5.1.3 experiment data for mini type in water drop of 1.51 m and lifting height of 10.8 m				
56	10	4.51	0.45	649.4
53	10	4.77	0.477	686.9
50	10	5.09	0.509	733.0
44	15	7.00	0.467	672.0
39	10	3.49	0.437	632.2
34	5	1.96	0.393	564.5
In general, the optimal frequency will be lower with the increase in (h/H) ratio of the water lift to the drop.				

The hydraulic ram has to be startet with a handle which opens the outer valve

2.5.2 Maintenance and repairing

Compared with the electrically operated pumping system or diesel pumping system, the maintenance of the hydraulic ram water lifting scheme is much easier. The maintenance for keeping the system properly operating includes:

- To keep the right operation frequency;
- To keep all nuts and screws tight;
- To make the measures for anti-frozen;
- To remove the garbage, straws or bushes from the inlet of feeding pipe.

Due to vibration caused by the water hammering, the fixed adjustment screw will move away from the optimal position. By measuring the operation frequency, it is easily known if the system is still working in the optimal condition, if not, by loosing the fixing nut and turning the adjustment screw anti-clockwise (in case that the frequency is higher) or clockwise (in the case that the frequency is lower) the optimal frequency could be reached again.

Although the hydraulic ram could continuously work without regular inspection, simple maintenance is necessary once a month or half month at maximum, especially to make sure that all nuts and screws are properly tightened. Since the hydraulic ram operation creates the vibration all the time, the nuts and screws, especially the nuts fixing the foundation bolts and the nuts fixing the air vessel with the lower part of the hydraulic ram, could become loose.

Under mild climatic conditions, winter will not create frost problems to systems that are kept working all the time, like domestic water supply systems. In southern parts of the P. R. of China, such as, Zhejiang Province and Sichuan Province, the system for the domestic water supply will not be harmed by low temperatures (lowest temperature -10^{o} C), which already occurred in several years. Operation of systems for irrigation will, however, be stopped during winter because the low temperature can cause damage.

Since the water resource protection is still far from the satisfaction in the rural area, very often there are garbage, straws, bushes or plastic waste flowing with the water. So a grid should be installed in front of the feeding tank, at least, there should be a grid in the inlet of the feeding pipe, for filtering all floating material before entering the hydraulic ram system.

Usually, small stones or sand will not disturb the operation, but they will reduce the life time of the rubber seals fixed in the discharging valve. But the plastic waste, straws, branches of the bushes or trees will be easily blocked between the delivery valve and let it fail to close tightly. In this case, the hydraulic ram is out of operation.

Besides the grid for filtering the garbage etc., it is also necessary to remove the garbage from the grid in certain intervals, otherwise, the garbage will block the grid and reduce the water flow into the feeding tank. Then the water level above the inlet of feeding pipe is getting lower till a certain level, the air enters into the hydraulic ram and reduces the water lifted, or stops the operation. In case that there is a grid in the inlet of the feeding pipe, when garbage blocks the feeding pipe, the hydraulic ram stops automatically, because the water flow is not sufficient to create kinetic pressure necessary for the operation of the system.

2.5.3 Problem shooting

Although the scheme is easy to install, operate and maintain, it is still be possible to have problems some time. In the following table there are problems listed, and also measures and solutions to solve these problems.

Problems and solution

Problems	Main causes	Solutions
Discharging valve could not be opened and closed automatically	1. Water level in the discharging pond is too low; 2. Stones, sand and other solid matters are blocked in the delivery valve; 3. Leakage of the discharging valve; 4. Improper frequency in operation; 5. Leakage in the inlet of delivery pipe.	1. Raise the water level in the discharging pond; 2. Remove the stones, sand or other solid matters from delivery valve; 3. Tight the screws in the discharging valve; 4. Adjust the frequency to the right one; 5. Find the leakage and repair.
Lifting water on and off, or less than expected	1. Insufficient air in air vessel; 2. Screw loose in delivery valve causes leakage; 3. Improper operation frequency; 4. Leakage in feeding pipe; 5. Air in the elbows in the delivery pipe; 6. Broken rubber seal in discharging valve. 7. Gap in the delivery valve is too big or too small.	1. Reduce discharging water level; 2. Tight the nuts and adjust concentricity; 3. Adjust the screw in discharging valve to find proper frequency; 4. Check the feeding pipe and tight screws in flanges; 5. Reinstall delivery pipe to avoid the pipe going down; 6. Replace the seal in discharging valve; 7. Adjust the gap.
No water lifted	1. No sufficient water entering hydraulic ram; 2. Big leakage in feeding pipe; 3. Delivery pipe was blocked, or stones or other solids in the air vessel; 4. Rusty in discharging valve or silt in the valve; 5. Seal in delivery valve or seal in discharging valve is broken.	1. Increase the water entering the hydraulic ram as much as possible; 2. Tight the screws in the flange or check out the leakage to repair; 3. Remove the stones or other solids; 4. Remove the silt or rusty to make the valve movable; 5. Repair or replace the broken part.
Vibration of the hydraulic ram	1. Nuts fixing the hydraulic ram with the foundation bolt is loose; 2. Screws fixing the ram base and the air vessel become loose; 3. Supporters for the feeding pipe are not strong enough.	1. Tight the foundation nuts; 2. Tight the screws in flange between ram base and the air vessel; 3. Fixing properly the supporters of the feeding pipe.

3 Water Supply Systems

3.1 Irrigation systems

The priciples and practices of water supply systems are listed here only. Gravity irrigation is the most spread autochtone artificial irrigation system. It is traditionally known by farmers. One can find this system word-wide. Other mechanical irrigation systems like sprinkler-dripp and siphon irrigation systems are industrially produced systems. Industries provide guidelines and installation instructions for their different types, pressure and water requirements. Sprinklers are often aditionally used for frost production, especially for fruit orchards and vegetables.

Drop irrigation is common in arid zones with extreme water shortage and high evaporation.

Sprinkler irrigation protects the blooming orchards and secures the harvest

Frost is most dangerous for orange orchards

Terrasses are flooded for rice plantation

3.2 Drinking water supply

Drinking water supply is subject of the local authorities. They have to observe the local hygiene regulations. Potable water is generally processed. Water supplied from drinking water systems should guarantee minimum norms. Water supplied to the public from open waters through hydraulic ram water lifting systems generelly do not fulfil these conditions. It is unprocessed raw water. In China, drinking water is traditionally boiled. Therefore, open waters are used for drinking in rural areas and generally accepted as drinking water after boiling.

There is a number of different techniques to process drinking water, such as gravel filters, active-coal-filters, or chemical processing measures. The water requirements demand their specific process. The chemical process by means of chlorification, for instance, is common for larger municipalities and demands high professional observation and maintenance. This technology is, however, not applicable for small villages.

The village water supply from higher located storage tang filled by means of a hydraulic ram

4 Technical and Economical Analysis

4.1 Comparison between the hydraulic ram and other water lifting system

42.7% of villages are without tap water and around 10% of the land is without an effective irrigation system in Zhejiang Province. Tap water and irrigation systems will improve the farmers' living standard and improve agricultural production. Several approaches are available for lifting water for both domestic and irrigation use:

- diesel pumping set
- electric pumping set
- gravity (with channel or pipe)
- hydraulic ram
- floating pump
- solar pump
- wind pump

Both, the diesel and the electric pumping set, consume conventional energy; the others can be operated by renewable energy. The gravity system and the hydraulic ram are driven by water power. The solar pump system is driven by the photovoltaic cell, which transfers the solar energy into electrical power. The wind pump system is driven by wind energy through the windmill. The floating pump is driven by the water current's kinetic energy.

■ **Gravity system**

The gravity irrigation system is the oldest autochtone one used in history. It utilises favourable topographical conditions to guide water from high land to lower land with channels or pipes. This is the most economical solution for irrigation, but unfortunately, the land which needs irrigation is often at a higher altitude than the water resource. Therefore, water-lifting technologies have been developed since humans developed agricultural production.

■ **Diesel and electric pump systems**

The diesel and electric pumping systems are well-known and used worldwide due to their convenience and, in many cases, a relatively lower initial investment. But in the remote areas the initial investment for the electric pump system is extremely high due to the cost of connecting it to the power grid. Transportation costs for diesel oil are also very high. Both systems' running costs are high. In some places the cost is as high as 3 yuan RMB for 1 m^3 of water for irrigation and finally paid by the consumers. The average cost is even higher in the mountainous and semi-mountainous areas.

With the conventional energy shortage and air pollution caused by conventional energy consumption, the diesel and electric pumping systems should be discouraged for providing the water supply, especially in the mountainous and semi-mountainous areas.

■ Solar pump

The solar pump system uses solar energy power to lift water. Since the power operating the pump is transferred from solar radiation by solar photovoltaic cells, they are the key part of the system. Although the production cost of the solar photovoltaic cell was greatly reduced in the 80’s and early 90’s, the cost of the photovoltaic cells is still high compared with the other energy system, despite its low running cost.

In the mid 90’s the price of the photovoltaic cell per peak Watt was 30-35 yuan RMB, too high of an initial investment for the farmers. The solar pump system can only be used in the daytime so it should be equipped with batteries for further use, but this makes the system even more expensive and increases the initial cost. The running cost is also increased because the batteries will need to be replaced periodically.

Zhejiang’s solar energy is relatively rich in the plains area, about 2000 hours of sunshine per year**,** which is advantageous for solar heat collectors for water heating. The sunshine hours are lower in the mountainous and semi-mountainous areas than in the plains. Compared with other local energy resources, for instance, hydraulic resources, solar energy is inferior for practical operation in mountainous and semi-mountainous areas.

The solar pump system is only competitive in remote areas, especially in the high mountains or on isolated islands where there is no power network available.

■ Wind pump

Wind energy is very rich in the coastal area, islands and high mountains. There are two ways to utilise wind energy to lift water, e.g. indirect wind energy utilisation and direct wind energy utilisation. Indirect utilisation transfers wind energy into electrical power to drive the electric pump system. Direct utilisation uses the windmill to drive the water pumps to lift the water.

Indirect wind energy utilisation involves two technologies, e.g. wind turbines for power generation and the electrical pumping system. It is appropriate for isolated islands and remote areas with rich wind resources; however the initial investment is high.

With direct wind energy utilisation, the windmill drives a piston pump to lift water. Since the wind speed is usually not stable, the windmill's rotational speed varies. The unstable rotational speed is not suitable for other types of pumps for instance, centrifugal pump, axial pump, etc. The rural development project experimented with the wind pump system, but due to technical problems and its high cost, it has not been practical to operate. In the Netherlands in Europe, the windmill operates the Archimedic screw mainly for drainage of low lying pastures.

■ Floating pump

The floating pump, e.g. water current pump, is driven by rivers or streams. It utilises the water current's kinetic energy. In 1990, BORDA supported a ZPSTC project utilising the floating pump, the BORDA pump, which had been successfully operated in Mali, Africa. The experimental operation in Zhejiang Province was not as successful as expected because of the following problems:

- This type of pump, with a horizontal axis, needs at least 2 metres of water depth which in many cases could not be found in Zhejiang Province;
- It needed frequent repair and maintenance because some parts were quickly worn out;
- The device is bulky, difficult to move, and disturbs traffic on the water stream.

It was necessary to accommodate the BORDA pump to the conditions in Zhejiang Province. The small rivers and streams are mostly shallow, about 1 metre. The larger rivers, with deeper water and appropriate conditions for fixing the floating pump and irrigation, are limited. The original floating pump's horizontal axis was changed to a vertical axis so that it could operate in shallow water, thus widening its use. This change had several advantages:

- to reduce the water depth needed;
- to eliminate the wear and tear on the main bearing;

- to allow the floating pump to operate in a water current from any direction;
- to reduce the device's size.

These advantages were realised by making experiments to find the optimal impeller shape and thus increasing lifting efficiency. More experiments are needed to finalise the materials and machine processes for batch production in factories.

The floating pump is fixed. The impeller for operation is fit to be floated in the water stream

■ **Hydraulic ram**

The hydraulic ram utilises water energy for lifting. The lift height can be as high as 30 times that of the water drop. But in its practical application, the ratio (h/H) of the lift to the water drop is in the range of 5 -15 times because the higher the lift is, the less quantity of water can be lifted. The practical application of the hydraulic ram since 1989 in Zhejiang and Sichuan Provinces has proved that this technology has been reliable and economical in the mountainous and semi-mountainous areas for both irrigation and domestic use. Compared with other systems, the hydraulic ram has its unique advantages in rural development and in environmental protection. Historically, the brothers Jacques and Michel Montgolfier invented the hydraulic ram in the late 18th century. The same also started the first hot-air balloon in Paris.

Table 4.1.1 lists the advantages, disadvantages, technical reliability, economical viability, and applicable areas for each of the above mentioned technologies.

Comparing the hydraulic ram with the other systems, it can be seen that in the mountainous and semi-mountainous areas, the hydraulic ram is the best choice if there is a hydraulic resource available because it is technically reliable and economically viable.

Table 4.1.1 comparison of several water lifting systems

Technology	Advantages	Disadvantage or limits	Applicable Area
gravity system	- good technical reliability and economic viability; - very limited running cost; - does not consume conventional energy; - limited maintenance; - professional operator is not necessary.	- no water lifting ability; - high initial investment in many cases.	mountainous and semi-mountainous
diesel pumping system	- good technical reliability in most cases; - easy to install and operate; - movable when necessary; - low initial investment; - pump water in most cases from rivers, streams & wells;	- consumes diesel oil; - emitting harmful gas; - high running cost; - needs frequent maintenance and repair; - needs professional operator.	all areas
electrical pumping system	- good technical reliability in most cases; - easy to install when there is a power grid; - low initial investment in many cases when the power grid is nearby; - pump water in most cases from rivers, streams & wells.	- consumes electrical power; - high initial investment when there is no power connection; - high running cost; - frequent maintenance, repairs necessary; - needs professional operator.	all areas
solar pumping system	- easy to install; - movable when necessary; - consumes no conventional energy; - pump water from rivers streams and wells; - good technical reliability.	- very high initial investment; - frequent maintenance, repairing are requested; - need professional operator; - uneconomical in many cases.	areas with the rich solar energy resources, especially in the condition without connection to the power grid.
wind pumping system	- doesn't consume conventional energy; - pump water from rivers, streams and wells; - relative lower running cost.	- high initial investment; - frequent maintenance and repair necessary; - less technically reliable; - less economical.	coastal areas and islands, and high mountains with rich wind energy resources and without power grid connection.
floating pump	- easy to install; - does not consume conventional energy; - movable when necessary; - low running cost; - professional operator is not necessary; - needs limited maintenance.	- pump water from rivers and streams with certain speed only; - higher initial investment than diesel and electrical pump systems in many cases; - less technically reliable.	areas where there are rivers and streams with certain water current speed, e.g. 0.5 - 2 m/s
hydraulic ram	- easy to install; - does not consume conventional energy; - very low running cost; - need hardly any maintenance and repairing; - professional operator is not necessary; - high technical reliability; - very economical in many cases.	- higher initial investment than electrical pumping system in some cases; - lift water from the streams with certain high water drop only.	mountainous and semi-mountainous areas with rich hydraulic resource, for instance, the water drop is more than 1 metres.

4.2 *Economic evaluation on water lifting scheme of the hydraulic ram by case studies*

4.2.1 General assessment

The installation investment of the hydraulic ram depends mainly on the site selection and the layout design of the system. Based on the questionnaires fed back, very high initial costs could be over 30000 yuan RMB (approx. 3750 €) when both the water drop and lift were high, and very low ones could be less than 10000 yuan RMB (approx. 1250 €). The initial costs include the hydraulic ram and the system, the investment for the water distribution networks for domestic water supply or the irrigation pipes and channels are not included. It is obvious that the initial investments are greatly different from place to place, due to the various topographical conditions.

According to the data collected from 18 villages, in which the hydraulic rams were installed in the early 90's, the average investment for one set was approximately 18000 yuan RMB, out of which 6000 yuan RMB for the hydraulic ram, 9000 yuan RMB for the raw materials of the civil engineering and installation costs, such as steel pipe, cement and bricks, and the remaining for the labour costs. (8 yuan RMB are approx. 1 €)

For whatever the hydraulic ram was installed, the hydraulic ram could more or less save the conventional energy while lifting the water. In general, the scheme's annual operation time for the domestic water supply is much longer than that for the irrigation purpose. So the hydraulic ram used for the domestic water supply could save more electricity. The saved electricity is the economic benefit for this hydraulic ram scheme. The social factor, the ease of life especially for women, cannot be measured, but is recognised by the beneficiaries.

The scheme for the irrigation, or simply for the rice land irrigation, has shorter operation period, usually three to four months. When the drought happened and the irrigation secures the harvest, the scheme has great economic result, but while rainfall is even and sufficient, the irrigation scheme has no obvious result. In the cases that farmers use the lifted water in an integrate manner, which leads to more benefits, such as:

- To increase the number of crops;
- To change the plantation structure;
- To plant the more valuable crop;
- To increase the crops area, etc.;
- To increase the forest area.

The hydraulic ram schemes also show great economic benefits. Therefore, the economic evaluation on the hydraulic ram scheme should be done by a general assessment and case studies.

Referring to the general assessment, the scheme used for the domestic water is taken as an example based on data of the average investment mentioned above. The initial investment is 18000 yuan RMB. The average daily quantity of the lifted water is around 100 m^3 (assuming the ratio (H/h) of the water lift and the drop is 10 and type 630 is installed). Assuming the price of the domestic water is 0.5 yuan RMB/m^3 and the scheme could operate 350 day yearly, the profit of the hydraulic ram scheme would be 17500 yuan RMB annually. Therefore, the payback period is around one year.

Reviewing the over 10-years-implementation of the hydraulic ram demonstration and dissemination project, several sets of the hydraulic rams for domestic water supply installed in the earlier period, e.g. in 1990 and 1991, have been kept running so far for many years without technical problems, and had to be stopped for only one or two days every six months or once a year for replacing the new rubber seal fixed in the discharging valve. In these villages the annual operation time was over 350 days. The price of the domestic water in the urban area is over 1 yuan RMB per m^3, for instance, 1.40 yuan RMB / m^3 in Hangzhou. The assumption of 0.5 yuan RMB / m^3 for the price of the domestic water and 350 days for the annual operation time are applicable and suitable. Therefore, the result of the short payback period for the hydraulic ram water lifting scheme is convincible.

In some cases, there were electrical pumping systems built in last years for the village domestic water supply. Due to the high costs of electricity and repairs, the farmers could not afford the scheme's running cost and had to stop using it. While the hydraulic resource is available, the hydraulic ram was installed to replace the electrical pumps. By the comparison between the initial investment for the hydraulic ram installation and the running cost and repairing and maintenance cost for the electrical pumping, showed very positive results which favour to the hydraulic ram schemes. As mentioned above, the hydraulic ram scheme should have 18000 yuan RMB as the initial cost for its installation, but its running cost is so limited that it could be ignored.

Referring to the electrical pumping system, the running cost and costs for repairing and maintenance, in average, are around 5000 yuan RMB per year. In this case, less than 4 years' running costs could make the initial investment of the hydraulic ram system paid back.

Therefore, it is easy to conclude that the result of the general evaluation of the hydraulic ram scheme is very positive. To make the detail investment analysis and ecological evaluation, the case study will show the practical result individually.

4.2.2 Case study for the domestic water supply system in Zhouzhu Village of Wuyi County, Zhejiang Province

Zhouzhu Village is located in the mountainous area of Wuyi County. Most of the villagers are of a minority nationality — they belong to the She People. There were 56 families with 210 inhabitants, when the hydraulic ram was installed in 1992.

Before the hydraulic ram was installed, there was no domestic water supply system. The water demand in the farmers' daily life should be carried from a small stream that was 500 metres away from the village. Carrying water was a hard job and created a lot of inconvenience to the farmers, mainly to the women, in their daily life. So the farmers in the village had been keen to build a domestic water supply system for long time.

In 1986, the village Community requested the local engineers from the county to estimate the initial investment of the domestic water supply system by electrical pumping. The estimation of the initial investment was about 30500 yuan RMB, including electrical wiring, electrical motor, pump, pump-house, delivery pipe between the pump and water tank and the construction cost of the water tank.

The cost of the delivering pipe between water tank and the village and the pipe for the water distribution to the families were extra, about 6000 yuan RMB more at that time. Since the villagers could not afford the initial investment, they had to drop this idea and the domestic supply system in the village was a dream for all villagers.

In 1992, with the help of the Wuyi County Science and Technology Commission and Wuyi County Rural Energy Office, a set of the hydraulic ram of type 420 was installed. The applied water drop was 4.6 metres and the lift was 63 metres high. The villagers invested 15000 yuan RMB for this water lifting scheme. Since the scheme was put into operation, at the end of August 1992, there was no interruption in the operating. It could lift 32 tons per day, which could basically meet the water demand for the farmers' daily life in whole village. The construction of the domestic water distribution network connected to each family cost 10000 yuan RMB extra.

Based on the data in Zhouzhu Village, it is possible to make investment and cost comparison between the electrical pumping system and the hydraulic ram water lifting scheme as follows:

- **Total initial investment:**

Electrical system:	30500 yuan RMB[1]
Hydraulic ram scheme:	21000 yuan RMB[2]

- **Operation cost per year:**

Electrical system:	
electricity charge	3200 yuan RMB
Maintenance cost[3]	500 yuan RMB
Operation cost	500 yuan RMB
Total	**4200 yuan RMB**

[1] It was estimated in 1986.

[2] It included 15000 yuan RMB for the construction materials and labour, 6000 yuan RMB for the 420 type hydraulic ram.

[3] Including repairing cost.

hydraulic ram scheme:	
maintenance and	
operation labour	500 yuan RMB
Total	**500 yuan RMB**

The overall costs for the electrical system and the hydraulic ram scheme could be described respectively with the following formulas:

$cost_{el}$= 30500+4200y (yuan RMB)

$cost_{hy}$= 15000+500y (yuan RMB)

Where:

- $cost_{el}$: overall cost of the electrical system;
- $cost_{hy}$: overall cost of the hydraulic ram scheme;
- y: operation years.

The result of the comparison could be shown in the Fig. 4.2.2.1.

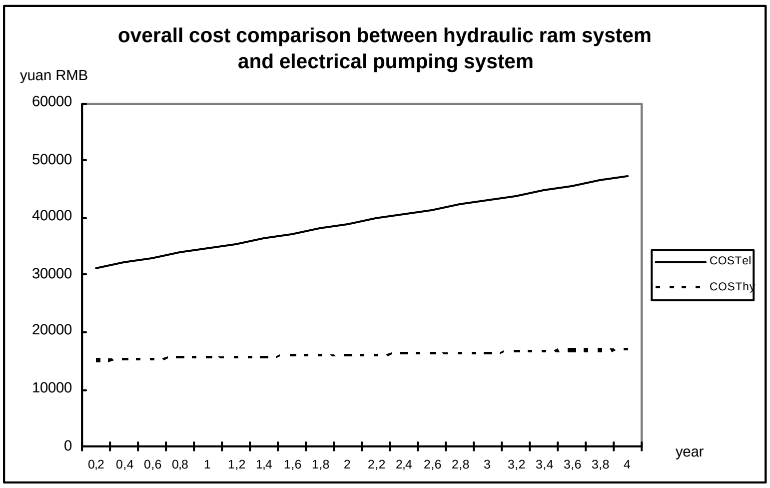


Fig. 4.2.2.1 overall cost comparison between electrical system and hydraulic ram scheme

It is very obvious that the overall cost of the electrical system is always higher than that of the hydraulic ram scheme.

Considering the Figure or the formulas, the result shows that in this case the hydraulic ram water lifting scheme was remarkably more economical than the electrical system.

The well guided self-help of the villagers with rural service technicians is a significant financial contrivution to the water supply scheme

4.2.3 Case study for the domestic water supply in the Yingchuan Village of Jingning County

Yingchuan Village is located in the Jingning County which is in the mountainous area in the southwestern part of Zhejiang Province. There were over 1000 villagers. There existed a village domestic water supply networks which was built with the investment of 20000 yuan RMB few years before a set of the hydraulic ram was installed in this village according to the farmers' demand.

The existing electrical pumping system cost at least about 3900 yuan RMB for the electricity charge and 1000 yuan RMB of the labour cost for the operation and daily maintenance. Due to the insufficient quality of electrical transmission, the voltage was not stable, which led to the damage of the electrical motor very often. The cost for the repairs and maintenance was as high as 3000 yuan RMB per year. For the local farmers it was difficult to afford the running cost to keep the electrical pumping system working.

In May 1992, a set of type 630 was installed and connected to the existing domestic water supply system. The drop applied was 4.2 metres and the lift was 33.6 metres. The total cost of the hydraulic ram installation was 19400 yuan RMB, out of this amount 6000 yuan RMB had to be spent for the hydraulic ram, 2000 yuan RMB for the feeding pipe, 2000 yuan RMB for the delivery pipes, 2470 yuan RMB for pump house, 1700 yuan RMB for the labour cost and 450 yuan RMB for the transportation fees. In this particular case, the evaluation should be done by the comparison of two alternatives, e.g. continue to use the existing electrical pumping system, or install the hydraulic ram to replace the electrical pumping.

The analysis is made as follows:

- initial cost:

continued use of the electrical system:	0 yuan RMB
installation of the hydraulic ram:	19400 yuan RMB

- operation cost per year:

continued use of the electrical system:

electricity charge:	3900 yuan RMB
labour cost:	1000 yuan RMB
repairing and maintenance:	3000 yuan RMB
Total	**7900 yuan RMB**

operation cost of the hydraulic ram scheme:

labour and maintenance:	500 yuan RMB
Total	**500 yuan RMB**

Based on the above data, following functions could be summarised to present the cost curves for overall costs of two alternatives respectively.

$Cost_{el}$=7900y (yuan RMB)

$Cost_{hy}$=19400+500y (yuan RMB)

Fig. 4.2.3.1 also shows two curves respectively for the overall cost of the electrical system and of the hydraulic ram scheme.

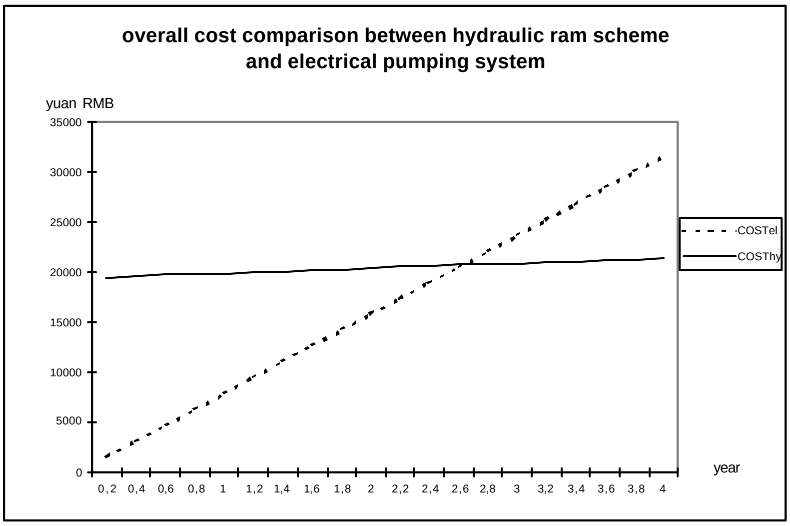


Fig. 4.2.3.1 overall cost for the electrical system and for the hydraulic ram scheme

By the calculation, the break even point of two curves is 2.62, which means after 2.62 years, the overall costs of the hydraulic ram scheme will be less than the overall cost of the alternative of continuing the operation of electrical pumping system. In other works, the total initial investment of the hydraulic ram scheme could be covered by saving the electrical change and repairing and maintenance cost in less than three years.

4.2.4 Case study of the mini type hydraulic ram installed in Zhoxi Village of Wuyi County

A family in Zhoxi Village had a house near a small stream. They used to carry the water on shoulder from the stream. A mini type of the hydraulic ram was installed for the family with the help of the rural energy office for the water supply for a family with 4 family members. The costs of the installation are listed as follows:

Feeding pipe (12.6 metres)	108 yuan RMB
Discharging pipe (40 metres)	200 yuan RMB
Delivery pipe (110)	150 yuan RMB
Fittings	26 yuan RMB
Cement	45 yuan RMB
Labour cost	200 yuan RMB
Total	**729 yuan RMB**

According to the experience of a local engineer, the costs of the discharging pipe could be saved, because it was only for the extra security in the severe flood. For this comparison, the local engineer made estimation for the initial cost of installation of the electrical pumping system. The initial cost of the electrical pumping system for the same purpose are listed as follows:

Electrical motor and pump	200 yuan RMB
Labour and material cost for digging a well	330 yuan RMB
Delivery pipe	125 yuan RMB
Cement	30 yuan RMB
Wiring	20 yuan RMB
Total	**705 yuan RMB**

Referring to the initial costs of the installation of mini hydraulic ram with the small electrical pumping system, there was no big difference between the two systems. But electrical system needs approximately 50 yuan RMB of electricity charge and 80 yuan RMB for repairing cost per year.

So for the same purpose, in this case, the water supply system with mini hydraulic ram was the better alternative than the electrical pumping system, because the cost of the hydraulic ram itself was not taken into account. If the cost of the hydraulic ram would be taken into account, the evaluation should be done by the comparison between the running cost of the electrical pumping system and the cost of the hydraulic ram.

For the electrical pumping system, the annual running cost is estimated as much as 130 yuan RMB, and the cost of the mini hydraulic ram was about 700 yuan RMB. It is obvious that the payback period of the hydraulic ram is about 5 years. Therefore, the alternative of the mini hydraulic ram scheme was still economical.

4.2.5 Case study of the irrigation with the hydraulic ram scheme in Changnan County

The Kenkou village is located in Changnan County which is mountainous area in southern part of Zhejiang Province. Kenkou Village has 58 families and 280 inhabitants. There are 7.3 hectares (110 mu) of rice land. Insufficient irrigation caused poor harvest, about 100 kg rice per mu (15 me = 1 hectare). Only one crop of rice could be planted in a year. In 25 metres lower than the rice land, there is a stream with running water throughout the year. If the water from the stream could be lifted for irrigation, the improved irrigation will not only increase the production yield of rice, but will also enable farmers to plant an additional crop besides rice.

In 1996, a set of 630 type of the hydraulic ram was installed in the village. The scheme has an applied water drop of 4 metres and lifts the water as high as 25 metres. The output of the lifted water was around 250 m^3 per day (in 24 hours), which could be used for the irrigation of 7.3 hectares of land. After the scheme was installed, besides the rice plantation, the farmers, for the first time, planted a special grass, which was the raw material for mat weaving, in November 1997. There were double benefits for the farmers in this case: the increase from the grass plantation and additional income due to the increase of rice yield from 100 kg to 350 kg per mu from a better irrigation with the help of the hydraulic ram scheme.

The total investments of the hydraulic ram installation (in yuan RMB):

One set of the hydraulic ram	9000
Feeding pipe, delivery pipe and fitting	8000
Installation cost (including materials and labour	5000
Total	22000 yuan RMB

The total benefit in a year (in yuan RMB) per mu*:

Income from the rice yield increased (250 kg/mu)	500
Income from the grass plantation (600kg/mu)	1200
Production costs	-350
benefits in a mu	1350 yuan RMB
benefits in total 110 mu	148500 yuan RMB

* (1 mu = 1/15 ha)

Comparing the benefits gained in a year with the initial cost of the installation of the hydraulic ram scheme, the payback period was very short, being less than months.

The results of these case studies have shown that the hydraulic ram is a very economical device for water supply in mountainous and semi-mountainous areas where there are rich water resources. Although not every site of the hydraulic ram application has brought such remarkable benefit mentioned in some case studies, every site more or less shows that the hydraulic ram is a reliable, appropriate and economical technology to raise the living standard, to promote the agricultural production, and to improve the villages' sanitation and hygienic conditions. It helps to protect the ecological environment, and contributes a lot to the sustainable rural development. The selfhelp component of the farmers is significant and helps to reduce cash investments.

4.3 *Overall evaluation of potential benefits from the hydraulic ram dissemination and improvement of the environmental protection in Zhejiang Province*

According to the results gained from the 'Overall Potential Study of the Hydraulic Ram Application in Zhejiang Province' (BORDA publication, 2001), there could be over 5000 villages in Zhejiang Province to have the water resources for the hydraulic ram installation and over 6000 sets of the hydraulic ram will be needed for both irrigation and for the domestic water supply for villages.

The detailed survey in Jingning and Jinyun Counties indicates 478 potential sites, where the hydraulic ram could be installed. 525 sets of hydraulic ram of 4 types are needed. With hydraulic ram dissemination, 429 villages out of 478 villages could have domestic water supply systems and an additional 2437 hectares of irrigated land. The other 49 villages already use electric pump systems to provide their house water supply; however, there are hydraulic resources so that the hydraulic ram could replace the existing systems.

Decentralised domestic water supply systems are a must if rural areas in Zhejiang Province are to reach the target of a minimal standard of comfort put forth by the government. The desire for domestic water is increasing along with rural development, increased incomes, and higher living standards, all of which easing the farmers' life. Domestic water supply is necessary for sanitation in the village and farmers' homes. Without domestic water supply, it is impossible to improve the level of sanitation or hygienic conditions in farmhouses.

According to the experience gained in the hydraulic ram projects, the hybrid water supply system for both domestic use and irrigation was more economical than the irrigation system alone because the operation time of the tap water supply system is much longer than the period for irrigation. People need water in their daily life, but when the climate is normal, irrigation is required for only three or four months. Since irrigation in the mountainous and semi-mountainous areas is far from satisfactory at most potential sites, both domestic water supply and irrigation should be considered. The irrigation system increases agricultural production yields, reduces dependence on the climate and its impact on agricultural production, and guarantees a harvest. The farmers also have alternatives in their choice of agricultural production and can generate more income.

When the benefits of the hydraulic ram are evaluated, it is difficult to quantify benefits brought to farmers from house water piped directly into their homes instead of being carried on shoulder. But it is certainly a significant step towards fulfilling the minimal comfort target. The benefits brought to agricultural production through irrigation driven by the hydraulic ram are also not easy to quantify because the benefits vary with the climate. For instance, according to the experience gained from 1989-1995 with the sprinkler irrigation system, the orchard's yield increased 10-30% in different climates because the sprinkler system not only irrigated the orchards, but also protected the blooming flowers from frost. Benefits are much more obvious when there is a draught or extensive frost than in the years with favourable weather.

Rice and vegetable production increased about 10% using the irrigated water lifted by the hydraulic rams. Besides the benefits mentioned above, with a sufficient water supply, the farmers could plant two crops instead of one, and could plant crops that need more water and are more profitable.

Paddy field irrigation with the hydraulic ram secures the harvest

In the villages in which the hydraulic ram replaced the existing electric pump system, the farmers experienced benefits other than saving electricity bills. Farmers in Yingchuan Village of Jingning County are a good example. In 1990, a set of type 630 hydraulic ram was installed to replace the existing electric pump system. Besides 3900 yuan RMB for the power bill that was saved every year, 1000 yuan RMB in labour cost and 2000 yuan RMB in repairs were saved annually. Therefore, in 1995, the villagers installed another set of type 630 hydraulic ram to meet the increasing water demand.

4.4 *Analysis of conventional energy saving in hydraulic ram dissemination and impact on environmental protection*

When evaluating the benefits brought about by hydraulic ram dissemination, it could be argued that the benefits are brought about by the lifted water alone because the diesel or electric pump can also lift water. But the hydraulic ram has the additional advantage of saving conventional energy which cannot be realised by the diesel or electric pumping systems.

On average, one set of type 630 hydraulic ram can function similar to a set of electrical pumps with the capacity of 6 kW. To supply the same amount of lifted water, the 6 kW electric motor would need to operates around 8 hours a day. Whereas the hydraulic ram does not require any operator, the operation of the electric pump systems need supervision of a professional operator, which makes it difficult to utilise these pumps round the clock. In this case, one will need three operators per day (3 x 8 hrs).

One set of the hydraulic ram can save 14400 kWh a year, equal to 7200 yuan RMB (electrical power price is calculated as 0.5 yuan RMB/kWh. In many places, the price was higher than 0.5 yuan RMB/kWh. The operation time was 300 days a year considering that during the dry season the water resource would not be sufficient to drive the hydraulic ram.

There have been more than 400 sets of hydraulic rams installed in more than 350 villages in China, with a rising tendency. These hydraulic rams can save over 6 million kWh a year (assuming operation time is 300 days a year).

If 6000 sets of the hydraulic rams were to be installed in the 5500 sites, the conventional energy savings would be 86.4 million kWh per year according to BORDA's potential study. This is equal to the total electricity generated in a medium-sized hydraulic power station with the capacity of 30 MW (assuming operation time is 3000 hours per year) or a small sized coal-fired power plant with the capacity of 15 MW (assuming operation time is 6000 hours a year). This coal-fired power plant would consume 48,000 tons of coal a year and exit around 960 tons of SO_2* and about 129,600 tons of CO_2** per year.

Hydraulic ram dissemination does not only save conventional energy, but it eliminates harmful gas emissions and protects the environment.

In 1998 Zhejiang's total electricity consumption was 54.7 billion kWh. The potential electricity to be saved by the use of the hydraulic ram would only be less than 0.2%, but due to the growing electricity shortage, the 'opportunity cost' of the electricity would be much higher than its market price. For instance, this electricity could be consumed in more profitable productions. Or the electricity saved could postpone the construction of a new power plant and the capital used for more urgent needs.

Therefore, at both the micro-level (in village level) and macro-level (at provincial or national level), saving conventional energy is much more significant than the energy savings in itself.

*: assuming the average Sulphur content is about 1%.

**: assuming in average, Carbon content in the coal is about 85%, while combustion 85% of Carbon can combine with Oxygen.

4.5 *Integrated socio-economic measure combined with the dissemination of the hydraulic ram*

On the dissemination of the hydraulic ram application, some socio-economic measures are also an integrated part of the project for rural development, such as:

- Income generation;
- Water resource protection;
- Wastewater treatment;
- Solid waste collection and treatment;
- Local renewable energy utilisation;
- Raise the farmers' living standard, especially improve the women's economic level and working condition;

- Protection of environment;
- Improvement of hygienic and sanitation conditions.

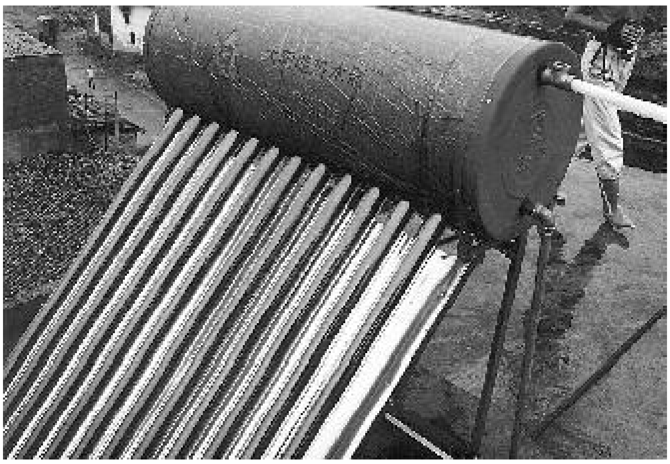
Combined with these socio-economic measures, our projects could bring more benefits to local people, solve problems in the development and promote the rural development. This is the concept of our integrated project. There are several reasons for the integration of these programms into the project:

- Overcome traditions in sanitation and hygiene and careless treatment of the surrounding, such as waste disposal in or beside the rivers or streams and insufficient removal of garbage and waste in the village;
- Very low attention to sanitation and hygiene conditions due to the poor living standard;
- Unawareness of the necessity of protecting water resources and the environment;
- Unawareness of the danger coming from industrial waste and residue disposal;
- Most farmers in the mountainous and semi-mountainous areas have an income far below 1 US $ per day. Income generating measures are necessary and effective for them.

Soya beans are a cash crop of high demand. Their local processing is a welcome additional income

For these reasons, the dissemination project of the hydraulic ram became an integrated development project. It includes activities for the promotion of agricultural production, raise of living standard, protection of water resources and the environment as well as collection and treatment of solid waste.

Broken fluorescent tubes, a solid waste classified as 'highly hazardous' are thrown away in the forest



The hydraulic ram enables the installation of solar heat collectors, an important contribution to improve the hygienic situation

5 Conclusion and Consequences

5.1 *Necessary structure*

■ **Training**

Over 400 sets of hydraulic rams have been installed and in operation since 1995. To promote hydraulic ram dissemination, training programs at different levels, i.e. government administrative level for policy and decision making, local technician level for site selection and installation, and for the farmers, are necessary. Training contents at different levels have different goals.

The government administration staff's training would appraise them of the hydraulic ram's advantages in the following aspects:

- Local renewable energy utilisation;
- Conventional energy saving;
- Environmental protection;
- Improvement of farmers' living standard.

The training for the local technicians and engineers would include:

- Suitable conditions for the hydraulic ram installation;
- Basic techniques for installation site selection and operation frequency adjustment;
- Teaching the farmers how to maintain the operation.

Training measures for farmers would provide general information about the hydraulic ram, its function, the integration into higher agricultural productivity, and house hygiene, as well. Training institutions and facilities would undertake training programs, and function on a consultant and supervisory level during dissemination of the hydraulic ram.

■ Consultancy

The technical reliability of the hydraulic ram has been proven. In nearly every site the hydraulic ram has been installed, it is functioning properly and with a limited amount of maintenance. But its economic viability is completely dependent on the site selection. When the water resource is not sufficient, when the distance between water resource and water demand is too long, when the water quality is below standard for its intended purpose, when the operation time is too short, etc., the hydraulic ram is not economical. Therefore, the site selection consultancy determines if the project is an economical success or not.

■ Supervision

A proper system layout will lower the initial investment. Construction quality control is important to ensure a solid foundation for the hydraulic ram, the right angle of the feeding pipe, and the proper connection between pipes, hydraulic ram, and feeding tank. Expert supervision can correct short comings early and will avoid unnecessary investments.

■ Follow-up service

Follow-up service is necessary to adjust the optimal operation frequency of the hydraulic. It will also teach the farmers how to maintain and adjust the frequency of the hydraulic ram.

Consultancy and follow up services are necessary even though the hydraulic ram has only two movable parts. The hydraulic ram can run with limited maintenance, and can operate 24 hours a day without any supervision. But anyhow, the rubber seal in the discharging valve must be replaced once or twice a year. The nuts in the foundation bolts and flanges must be periodically tightened. The whole system must be totally emptied of water during frost periods.

Since the operation is very simple and maintenance is limited, farmers might think that the hydraulic ram does not need maintenance, causing problems. For example, the foundation bolts will break if the loose nuts are not tightened in time. Small stones, and other solid matter carried along with the water into the vessel may affect the delivery valve not to close properly.

Spare parts should always be available. The rubber seal in the discharging valve is the most frequently replaced part. Nuts and bolts are also needed and should be a part of the repair kit of the follow-up service.

5.2 Necessary production capacity

Since the beginning of the 90's, BORDA has transferred hard and software for the hydraulic ram production to the Zhejiang Province, which has two companies that can manufacture 4 types of hydraulic ram. Their production capacity is around 600-700 sets a year, more than sufficient to reach the demand in Zhejiang Province in the near future.

Top quality control is most important in two processes, casting the body and welding the air vessel, because any small leakage affects the operation of the hydraulic ram leading to failure. Special testing equipment is needed for production quality control.

The Lishui Equipment Installation Company, one of the companies manufacturing the hydraulic ram, uses an X-ray detector to control the casting and welding quality. Lacquering and other machinery processes also need good quality control to avoid unnecessary losses to the companies and to the farmers, as well.

With the dissemination of the hydraulic ram, the expansion of the production capacity can easily be realised in a short time. Therefore, availability of hydraulic rams will not be a problem in Zhejiang Province.

5.3 Financial schemes

Credit and loan systems were popular at the time the planned economy was implemented. But since 1980 these systems cannot meet the requirements of the developing market economy. The people's commune production systems were dissolved in the rural areas after introduction of the economic reform.

Except for the crop production, the individual farmer can rarely get a loan for a non-production investment. Individual villages cannot get loans from banks for village welfare projects, such as village planning, path and road construction, or village tap water supply system construction, because the credit and loan system has not been effectively developed for the private person in rural areas. Farmers cannot provide capital securities. They are not the owners of the land they use. Land is state property.

In villages where farmers wanted to install the hydraulic ram, the necessary investment was collected by the local authorities from each family that would benefit and from the village collective income, besides some limited subsidy for pipes and the hydraulic rams. But the financial ability of villages in the mountainous and semi-mountainous areas is very limited. The village collective incomes are limited and individual family's ability to pay is poor. Therefore, before the village commission makes decision to install a hydraulic ram for house water supply systems in the village, they have to consider the financial ability before.

To promote hydraulic ram dissemination, the limited credit and loan systems should be developed to provide help for improving the farmers' living standard. Self-help, such as borrowing from relatives and friends, will still play a very important role in rural development, and consequently in the dissemination of the hydraulic ram.

5.4 Development of corresponding governmental policy on this issue

Hydraulic ram dissemination is a project to utilise renewable energy, improve the living standard and help to protect the environment. It is in conformity with China's Agenda 21. A favourable policy regarding the dissemination of the hydraulic ram by the government would be a positive push forward. The government policy should include subsidies, loan, taxes, etc..

At different levels, the government could make funds available to promote economic development and raise the living standard in the mountainous and semi-mountainous areas. Some of these funds could be used to subsidise hydraulic ram dissemination. Besides these funds, the Water Conservation Bureaux and Hygiene Commissions have funds for the clean water supply, which could be contributed to the dissemination of the hydraulic ram. The appropriate policy could guide these funds to the village water supply systems, which would use the technology of the hydraulic ram.

The government policy could guide distribution of small loans to help villages build domestic water supply systems. One of the policy's functions would be to make default regulations to help insure that the farmers would pay back the small loans according to plan.

Income taxes paid by companies who manufacture the hydraulic ram could be reduced for a certain period to make the hydraulic ram's price affordable for farmers. Such tax adjustments and reductions could be involved in the favourable policy for development and dissemination of appropriate technologies that encourage renewable energy utilisation and environmental protection. Farmers should be treated as small enterprises.

According to **China's Agenda 21's** main policies for sustainable development, the development of clean coal technology and other forms of clean and renewable energy sources is a priority. **China's Agenda 21** provides for financial resources and mechanisms that will guarantee the execution of sustainable development measures. There are three aspects in view of the financial resources and mechanisms:

- Integration of **China's Agenda 21** into National Economic Development plans;
- **China's Agenda 21's** Development Funds;
- Financial, taxation and economic legislation for sustainable development.

5.5 Dissemination project procedure

The definition of the hydraulic ram system includes the transfer of water from the lower water resource to the higher water storage tank. The hydraulic ram system consists of feeding tank, feeding pipe, hydraulic ram foundation, hydraulic ram, delivery pipe and water storage tank. The materials needed to install the hydraulic ram include: steel feeding and delivery pipes; cement, bricks, sand and stones for the feeding tank, installation foundation, and storage tank; etc..

The distribution networks from the water storage through water distribution pipes to the families or other water end-users is the same system if the water is lifted by the hydraulic ram or by electric or diesel pumping systems.

Usually, the domestic water supply system is more expensive than the irrigation system because the water distribution network that supplies each family is a more complicated system. On average, the total initial cost for a house water supply system varies from 50,000 yuan RMB to 100,000 yuan RMB depending on how many families are connected to the domestic water supply system. Excluding the hydraulic ram, the hydraulic ram system costs vary from 15,000 to 20,000 yuan RMB depending on the geographic and topographic conditions.

The following is an example of the materials needed for a typical hydraulic ram system (2.5 m water drop, 25 m lift, one set of type 630 hydraulic ram):

- 20 metre steel pipe with a diameter of 150 mm;
- 40 metre steel pipe or partly polythene pipe with diameter of 75 mm;
- 15 - 30 tons of cement;
- materials like sand, stone and bricks, etc.
- 150-200 man days of labour cost.

If the hydraulic ram is installed at all potential sites, the total cost will be about 550 million yuan RMB, a huge investment. But several financial resources are available. The main financial resource are the funds collected from every family that is benefited, i.e. the self-help activities, which should play the main role in the project. Other resources are government subsidies at different levels and loan assistance guided by the government's favourable policies. International financial assistance is also a possible financial resource, but it only plays a lever fulcrum to promote the dissemination process.

The procedure for the dissemination of the hydraulic ram consists of many steps. Since the implementation of the projects with BORDA in 1988, some steps have been taken in Zhejiang Province, for instance:

- technical training in selected places;
- demonstrations on a small scale;
- seminars on the installation and operation of the hydraulic ram in villages;
- transfer of technology for manufacturing the hydraulic ram;
- technical and economic evaluation of demonstration projects;
- technical training programs for further demonstrations in areas outside of the selected sites;
- potential application study taking into account resources, economic and technical factors.

The projects with BORDA from 1988 have had remarkable results and are a good base for the hydraulic ram dissemination.

People living in the mountainous and semi-mountainous areas need help for their economic development and to improve their living standard . Their strong will to participate in the water supply projects, to contribute in cash or to work as valorised non-cash contribution, substitudes governmental necessities for a sustainable development. Governmental investments are more significant in industrial development than in agricultural development. Additionally, agricultural development in mountainous areas is more difficult and expensive. The differences between infrastructures of industrial and rural areas are obvious.

According to the 1996 detailed survey, the next 2-3 years was the first phase of dissemination. Five counties; Jingning, Jinyun, Yunhe, Taishun and Wencheng, which are all in Lishui and Wenzhou, will be the focal points for the dissemination project. These counties are to more than 75% mountainous, and the farmers' incomes are significant lower than the average level in the Province; therefore, installation subsidies will be put into the next national plan. 150-200 sets of hydraulic ram should be installed in these counties.

The second phase was the 5 years lasting project following the first phase. The focal points would be around 10 counties in the Province. The subsidy for the installation will be less and partly replaced by small loans. By the end of this phase, it is expected that 500-800 sets of hydraulic ram will have been installed in the Province. In the process of reaching this target, the hydraulic ram will progressively enter the market place and become an alternative water-lifting device for purchase. When the hydraulic ram enters the market place, dissemination has been reached.

5.6 Recommended measures

For reaching the target of the hydraulic ram dissemination, the following measures should be taken in the project, supported by county governments:

- provincial and county level workshops to develop policies for the dissemination of the hydraulic ram within the framework providing a reliable supply, conserving natural resources, and protecting the environment;
- creation of a permanent monitoring structure for renewable energy utilisation and water lifting systems. This permanent monitoring structure can be combined with existing governmental organisations, such as, the Rural Energy Office, etc.;
- training courses at both the administration and field work levels to

plan and execute hydraulic ram projects to lift water

- public relations, such as advertising and promotion, as tasks for hydraulic ram manufacturers;
- public relations through print and audio-visual media to spread the information of the hydraulic ram application and its results.

Appendix

Brief Introduction of Zhejiang Province

1 *Geography and topography*

Zhejiang Province is located at China's east coast. It borders on Shanghai Municipality, Anhui, Jiangsu, Jiangxi and Fujian Provinces. It covers an area of 101,800 square kilometres from northern latitude 27^{o}06' to 31^{o}11' and from eastern longitude 118^{o}0' to 123^{o}10'. Zhejiang Province makes up 1.06% of China's 9.6 million km^2.

The mountainous and semi-mountainous areas of Zhejiang Province make up 71.7% of the total surface area. The plain area, which is less than 50 meters above sea level, makes up 23.2%. Water surfaces, such as, rivers, lakes, and streams, cover 6.4%. The Province's topography is high in the west and low in the east; therefore the mountains are mostly in the middle and western part. Zhejiang Province has 8 river systems:

- Qiantang River,
- Chao'e River
- Yongjiang River
- Jiaojiang River
- Feiyunjiang River
- Aojiang River
- Oujiang River
- Shaoxi River

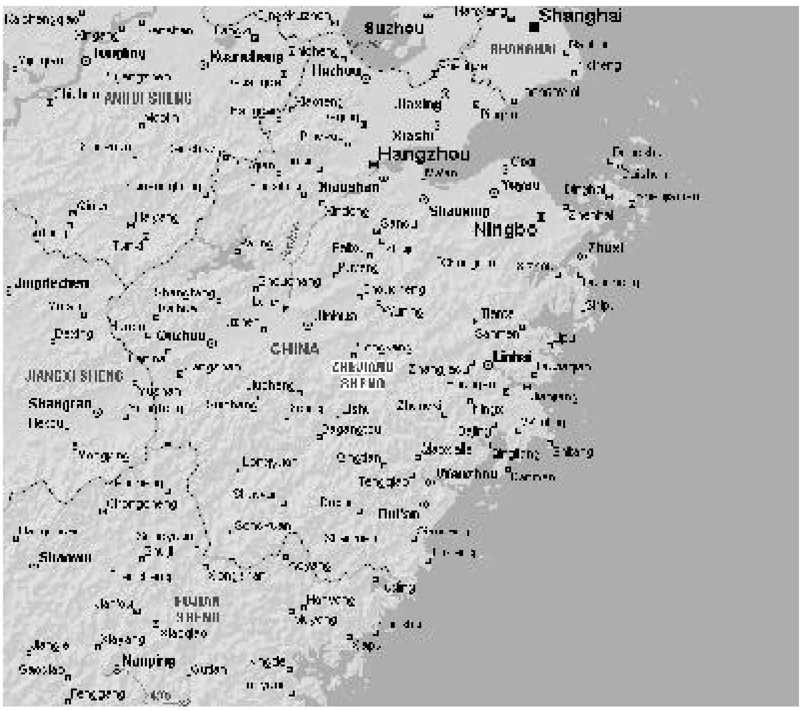
Except for the Qiantang River, which originates in the Anhui Province, all rivers originate in the western part of the Province and flow into the East China Sea. Only Shaoxi River flows to Tianhu Lake in the northern part of the Province.

Table 1 catchments and lengths of 8 river systems in Zhejiang Province

River Name	***Origination of River***	***River Mouth***	***River Length (km)***	***River Catchment (km^2)***
Qiantang	Xiouling County in Anhui	Hangzhou	428	35700*
Oujiang	Longqian County	Wenzhou	388	17859
Jiaojiang	Nu'ken Mountain	Jiaojiang City	198	6519
Yongjiang	Xioujian Mountain	Zhenhai	121	4294
Chao'e	Qigong Mountain	Shanjiangkou	192	6046
Feiyun	Shenyuan Mountain	Rui'an County	185	3717
Aojiang	Yuling Mountain	Pingyang County	82	1514
Shaoxi	Tianmu Mountain	Huzhou	150	4759

**only in Zhejiang Province*

The above table shows only the lengths and catchments of the main rivers, not their branches. If the data of the branches was included, the length and catchment would be much higher.



Map of Zhejiang Province, China

2 Climate

Zhejiang Province has a subtropical climate with four seasons. The main wind direction is from the northwest in the winter, and from the southeast in the summer. Climatic feature are:

- long sunshine period;
- rich precipitation;
- high relative humidity;
- mild temperature.

The annual average temperature, except in the high mountains, is from 15-18°C. The coldest monthly average temperature (in January) is 2.5-7.5°C, and the hottest monthly average temperature (in July) is 26.5-29.5°C. The temperature is lower in the north than in the south. One year averages 243-276 frost-free days and 1800-2100 hours of sunshine. The annual average days of rain are 140-180, and the average precipitation is 1100-1900 mm a year. Rainfall distributes unequally in the four seasons with summer and autumn the dry seasons. The annual average relative humidity is above 75% on the mainland and above 80% on the coast and islands.

Table 2 main meteorological data in Zhejiang Province

	January	February	March	April	May	June
average temperature (1961-90) °C	5.0	6.0	10.0	15.8	20.6	24.3
average precipitation (1961-90) mm	55.1	85.6	119.2	141.8	172.6	206.5
average sunshine (1961-90) hour	125.1	104.1	123.6	141.7	155.3	153.7
	July	**August**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
average temperature (1961-90) °C	28.3	28.1	23.9	20.4	13.2	7.3
average precipitation (1960-90) mm	138.2	142.4	165.1	83.2	62.4	44.5
average sunshine (1961-90) hour	243.8	246.0	173.0	164.1	146.0	147.8

Source: Zhejiang Statistical Yearbook 1995

3 *Political and administration structure*

Zhejiang Province has 10 municipalities and 1 prefecture. Each municipality or prefecture has several cities, counties and districts under the city administration. The administrative division in Zhejiang Province is shown in Table 3.

The Provincial Government consists of several functioning departments, such as Planning and Economic Commission, Science and Technology Commission, Agricultural Bureau, Industrial Bureau, etc. The municipal, city and county governments also consist of similar departments with similar functions. For instance, at the provincial level, there is the Provincial Science and Technology Commission and at the municipal level and county level there are the Municipal Science and Technology Commission and County Science and Technology Commission.

This administrative structure helps the government to understand the local condition with its problems, which facilitates the selection and implementation of related projects.

Table 3 administration division

name of municipalities and prefecture	***number of counties, cities and districts in county level***				***names of counties, cities and district under city administration***
	total	***district***	***city***	***county***	
Hangzhou	12	5	4	3	Shangchen, Xiacheng, Xihu, Gongsu, Jianggan Districts, Xiaoshan, Jiande, Fuyang, Yuhang Cities, Tonglu, Ling'an and Shun'an Counties
Ningbo	11	5	3	3	Chenghai, Jiangdong, Jiangbei Haishu, Beilun Districts, Yuyao, Chixi, Fenghua Cities, Changnan, Ninghai and Yenxian Counties
Wenzhou	11	3	2	6	Lucheng, Longwan, Ouhai Districts, Rui'an, Yueqing Cities, Dongtou, Yongjia, Pingyuang, Changnan, Wencheng and Tanshun Counties
Jiaxin	7	2	3	2	Urban and Suburban Districts, Haining, Pinghu and Tongxiang Cities, Haiyian and Jiashan Counties
Huzhou	3			3	Deqing, Changxin and Anji Counties
Shaoxin	6	1	2	3	Yucheng District, Zhuji and Shangyun Cities, Shaoxin, Shenxian and Xinchang Counties
Jinhua	9	1	4	4	Wucheng District, Lianxi, Dongyang, Yiwu and Yongkang Cities, Jinhua Wuyi, Pujiang and Pan'an Counties
Qiuzhou	6	1	1	4	Kecheng District, Jiangshan City, Quxian, Changshan, Kaihua and Longyan Counties
Zhoushan	4	2		2	Putou and Dinghai Districts, Daishan and Shensi Counties
Taizhou	9	3	2	4	Luqiao, Jiaojiang and Huangyan Districts, Linghai, Wenling, Xianju, Tiantan, Shanmen and Yuhuan Counties
Lishui Prefecture	9		2	7	Lishui and Longqian Cities, Qingtian, Qingyuan, Jinyun, Shuichang, Shongyang, Yunhe and Jingning Counties
in whole province	87	23	23	41	

Source: Zhejiang Statistical Yearbook 1999

4 Population

In 1994, 43.4 million people in 13.21 million families were living in Zhejiang Province. The rural population was 35.65 million (82%), and the urban population was 7.76 million (18%). Zhejiang Province is one of the country's most densely-populated provinces. In every square kilometre, there are 434 people. Table 4 reflects Zhejiang's population from 1981-1998.

Table 4 population data

year	*numbers of families (million)*	*population (million)*	*rural population (million)*	*urban population (million)*	*population growth rate (%)*
1981	9.66	38.72	33.62	5.09	1.33
1982	9.91	39.24	33.88	5.37	0.99
1983	10.14	39.63	34.13	5.50	0.76
1984	10.38	39.93	34.25	5.68	0.93
1985	10.81	40.30	33.95	6.34	0.99
1986	11.22	40.70	34.17	6.53	1.25
1987	11.67	41.21	34.55	6.66	1.19
1988	12.11	41.70	34.88	6.82	0.96
1989	12.40	42.09	35.15	6.93	0.65
1990	12.59	42.35	35.38	6.97	0.61
1991	12.77	42.61	35.55	7.06	0.59
1992	12.98	42.86	35.60	7.25	0.63
1993	13.11	43.13	35.63	7.50	0.65
1994	13.22	43.41	35.65	7.76	0.67
1995	13.40	43.70	35.67	8.02	0.69
1996	13.54	44.00	35.70	8.30	0.50
1997	13.70	44.22	35.57	8.65	0.57
1998	13.89	44.47	35.40	9.07	

Source: Zhejiang Statistical Yearbook 1995-1999

Since the national policy for family planning has been introduced, the average annual population growth rate has been stabilised at 0.82% from 1981-1998. In the 90's, the annual growth rate was around 0.6%. But the growth rate of the rural population differs from the growth rate of the urban population. From 1981 to 1998, the average annual growth rate of the rural population was 0.31%, but the average annual growth rate of the urban population was as high as 3.5% in the same period. The main reason was the migration from rural to urban areas even though there were strict measures to control this migration.

In the process of socio-economic development, migration from rural to urban areas has been the inexorable trend in many developing countries creating urban problems. Along with strict residence management, small town and rural industry development will help motivate people to stay in their hometown and not migrate to the urban areas.

5 Energy supply infrastructure

In 1998 the yearly coal production output was 0.95 million tons in Zhejiang Province, shown in Fig. 1.

Fig. 1 reflects how limited coal production in Zhejiang Province was and that self-mined coal amounted to only about 6% of the total coal consumption.

Electrical power generation has developed quickly in Zhejiang Province. Fig. 2 reflects the increase of power generation from 1990 to 1998.

The construction of electrical power plants developed fast due to the severe shortage in the power supply. The average annual increase rate of power generation was 10.8%. But this pace was still slower than the socio-economic development. There is still a gap between power supply and demand.

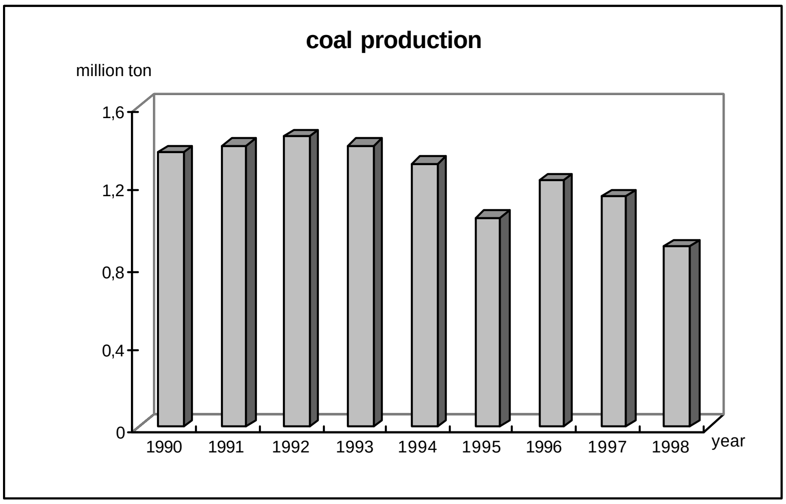


Fig. 1 coal production in Zhejiang Province

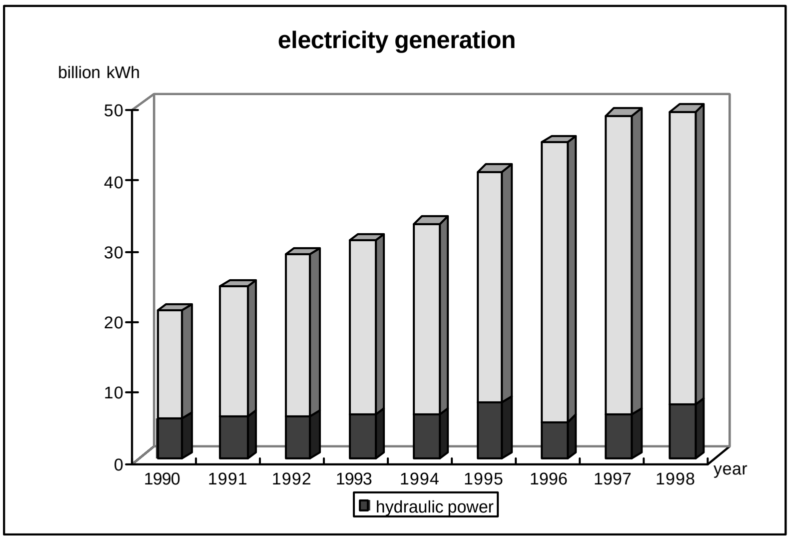


Fig. 2 electricity generation development in Zhejiang Province

Table 5 development of power generation in Zhejiang Province

year	1990	1991	1992	1993	1994
total power generated (10^9 kWh)	20.866	24.232	28.416	30.860	34.101
generated from hydraulic power stations (10^9 kWh)	5.6	5.83	5.845	6.125	6.193
increase rate of the total power generation (%)		16.1	18.9	7.1	7.6
year	**1995**	**1996**	**1997**	**1998**	
total power generated (10^9 kWh)	40.711	44.836	48.577	49.211	
generated from hydraulic power stations (10^9 kWh)	7.825	5.225	6.139	7.59	
increase rate of the total power generation (%)	19.3	10.1	8.3	1.3	

Source: Zhejiang Statistical Yearbook 1999

Self-generated power made up about 82% in Zhejian Province. The remaining 18% were supplied by the eastern China power grid, (which covers 6 provinces and Shanghai Municipality). In principle, it can provide some electricity to Zhejiang Province; however, these 6 provinces and Shanghai are all bigger energy consumers than producers. The electricity shortage exists in the area that the eastern China power grid covers. Therefore, the power consumers' demand in Zhejiang Province cannot be satisfied.

Transportation facilities in Zhejiang Province have been improved. Energy transportation within the Province is dependent on railways, roads and river channels. Sea transportation is mainly done for energy transportation from overseas, like crude oil, and within the coastal areas of the province. Table 6 shows the development of transportation facilities.

Table 6 main transportation infrastructure

year	1990	1991	1992	1993	1994
railway (km)	832.6	835.8	867.4	886.1	920.5
road ((km)	30195	30700	31924	32838	33438
- first grade					26
- high way			7	7	7
channel (km) (1m depth more)	3954	3954	3954	3954	3954
year	**1995**	**1996**	**1997**	**1998**	
railway (km)	921		1051	1196	
road ((km)	34329	35335	36127	38900	
- first grade	110	189	414	669	
- high way	94	158	168	344	
channel (km) (1m depth more)	3967	3967	4439	5948	

Source: Zhejiang Statistical Yearbook 1995-1999

From 1990-1998, railroads' length increased at an average annual rate of 4.6%, and the roads' length increased at an average annual rate of 3.2%. Channels, which are the main short-distance coal transportation to many places in the Province, were not lengthened. Energy consumption has increased faster than the improvement of transportation system.

6 *Economic development with emphasis on agriculture and rural industries*

Since the beginning of the 80’s, the rural economy has developed very fast. The main features of development are:

- more market orientated agricultural production;
- more products available;
- higher productivity;
- fast development of the rural industry;
- higher living standard in most rural areas.

The economic reform in the rural area was started in the beginning of the 80’s. Before the reform, the main productions in the rural area were agriculture, forestry, husbandry and fishery. Agricultural production included grain crops, oil bearing crops, cotton, jute, sugar, vegetable, teas and fruits, and mulberry for silkworms. Forestry included forestation and wood processing, along with wood and bamboo products. Husbandry included raising cattle, pigs and poultry. Fishery production was of two kinds, catching fish (mostly from the sea) and aquaculture (in fresh water and in shallow sea water). After the beginning of the 80’s, the rural industries developed quickly and their output values increased much faster than the traditional production in the rural areas. Table 7 shows the development of agriculture and rural industries in Zhejiang Province from 1990-1994.

In 1980, traditional rural production’s total output value was 9267 million yuan RMB including agriculture, forestry, husbandry and fishery, as compared with rural industries’ total output value which was only 4000 million yuan RMB, or less than half of the traditional production. But in 1998, the output of traditional agricultural production was 100366 million yuan RMB, but the output of the rural industries was 1010876 million yuan RMB, the rural industries’ output was around 10 times that of the traditional rural production.

Table 7 production development in rural areas

Unit: million yuan RMB

total output value of productions	***1990***	***1991***	***1992***	***1993***	***1994***
tradition rural productions	33604	36864	40479	49970	70721
-agriculture	19948	21721	22646	27485	37297
-forestry	1600	1742	2101	2980	4192
-husbandry	7966	8220	9309	10168	15179
-fishery	4090	5181	6423	9337	14053
rural industries	52638	69821	97773	151428	243252

Source: Zhejiang Statistical Yearbook 1995

The average annual increase rate of rural traditional production was 14.1% from 1980-1998, but the average annual increase rate of rural industries was as high as 136%. More and more people living in rural areas shifted from the traditional agricultural production to industrial production. Table 8 reflects this change.

Table 8 main data for the rural labours

unit: million persons

	1990	**1991**	**1992**	**1993**	**1994**
total rural labour	2035	2072	2099	2106	2101
- in rural tradition production (10^6 persons / %)	1337 / 65.7	1349 / 65.1	1339 / 63.8	1239 / 58.8	1187 / 56.5
- in rural industries (10^6 persons / %)	698 / 34.3	723 / 34.9	760 /36.2	867 / 41.2	914 / 43.5
	1995	**1996**	**1997**	**1998**	
total rural labour	2097	2096	2099	2096	
- in rural tradition production (10^6 persons / %)	1145/54.6	1123/53.6	1106/52.7	1102/52.6	
- in rural industries (10^6 persons / %)	952/45.4	973/46.4	993/47.3	994/47.4	

Source: Zhejiang Statistical Yearbook 1995-1999

The economic growth of people in rural areas is on the fringes of traditional industrial plans. Farmers offered their land lease contracts to industrial enterprises. There is a peculiar market on land titles because land is generally owned by the government, only. The industrial development mainly of small and medium sized enterprises has increased the average income of the rural people and brought some prosperity to these regions. With the rapid development of rural industries, the living standard in rural areas also improved.

In the remote areas of Zhejiang Province, industrialisation has limited possibilities. Traditional agriculture is the only source of income being far below 1 US $ per day, there. The necessary increase of economic growth in these regions is depending on the development of agricultural productivity. The statistics of the UN say that China can export food today, but in about 15 years or less China will be the biggest importer of food in the world.

Technical Drawing of Hydraulic Ram

This handbook is meant for policy makers, engineers and field workers to promote and disseminate the use of renewable energies - here hydraulic ram systems for water supply in agriculture and households - towards protection of the environment and natual resources in the process of the **Agenda 21** .