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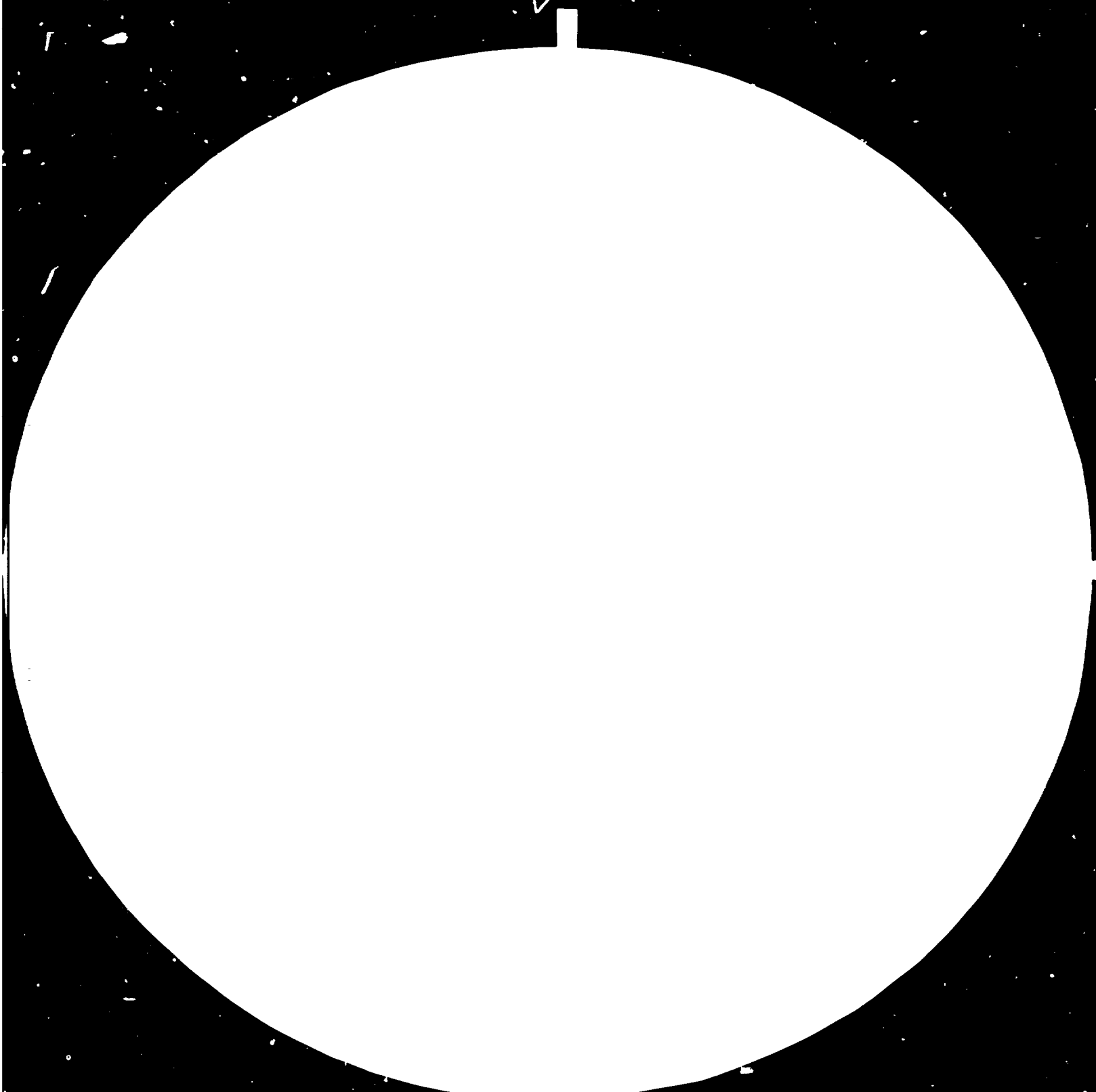

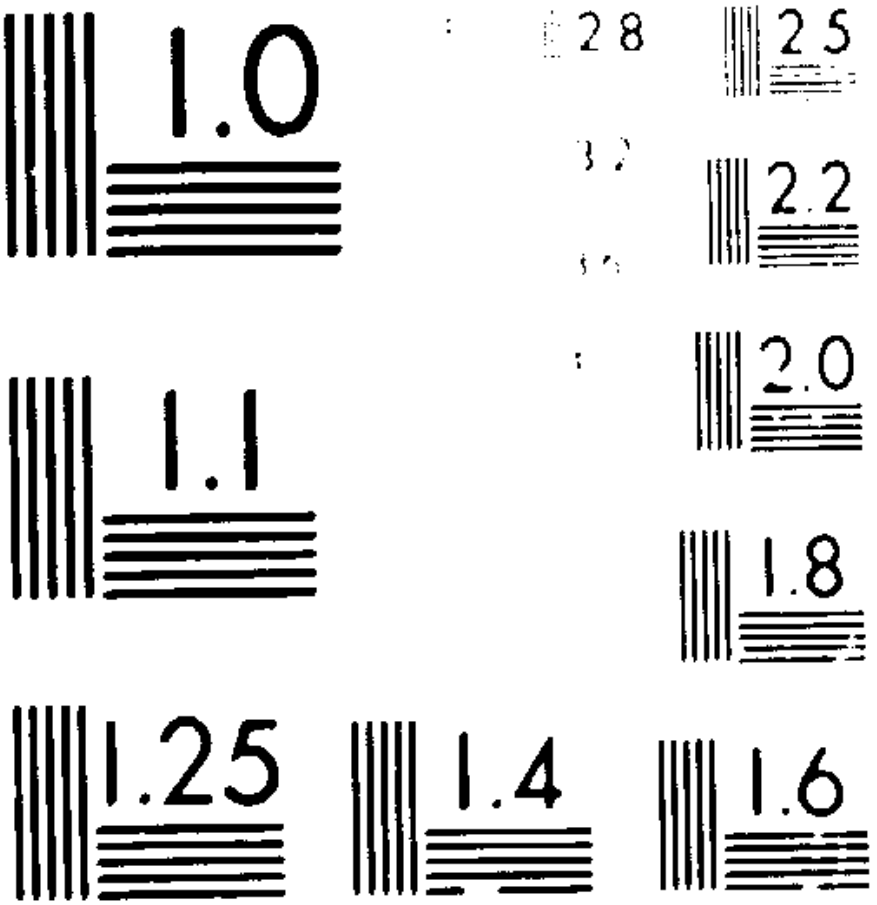
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MINI HYDRO POWER PLANTS IN THE FEDERAL REPUBLIC OF GERMANY - THE DEVELOPMENT AND SITUATION OF MINI HYDRO POWER PLANTS*

by

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Waldemar Pförtsch**

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** Supported by Wolfgang Bogenrieder, Technische Universität Berlin.

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Contents

I. The development of mini hydro power plants in the Federal Republic of Germany

1. Energy - resources and supply

In the industrial countries - such as the Federal Republic of Germany - consumption of energy increased considerably during the past decades (Appendix I).

Pressure groups in politics and private industry see a possibility of meeting the expected increase in demand by extensive utilization of nuclear energy.

However, the unsolved problems connected with the use of nuclear energy and the shortage of raw materials available only to a limited extent make considerations necessary concerning the saving of energy and the improved utilization of regenerative energy sources.

The water power potential has been utilized for centuries. Today more than 60% of it are harnessed. To meet the varying demand for electrical energy, thermal electric power plants and river run power plants as well as water storage power plants have been erected (see Figure 1). 4.5% of the demand are covered by hydro power plants.

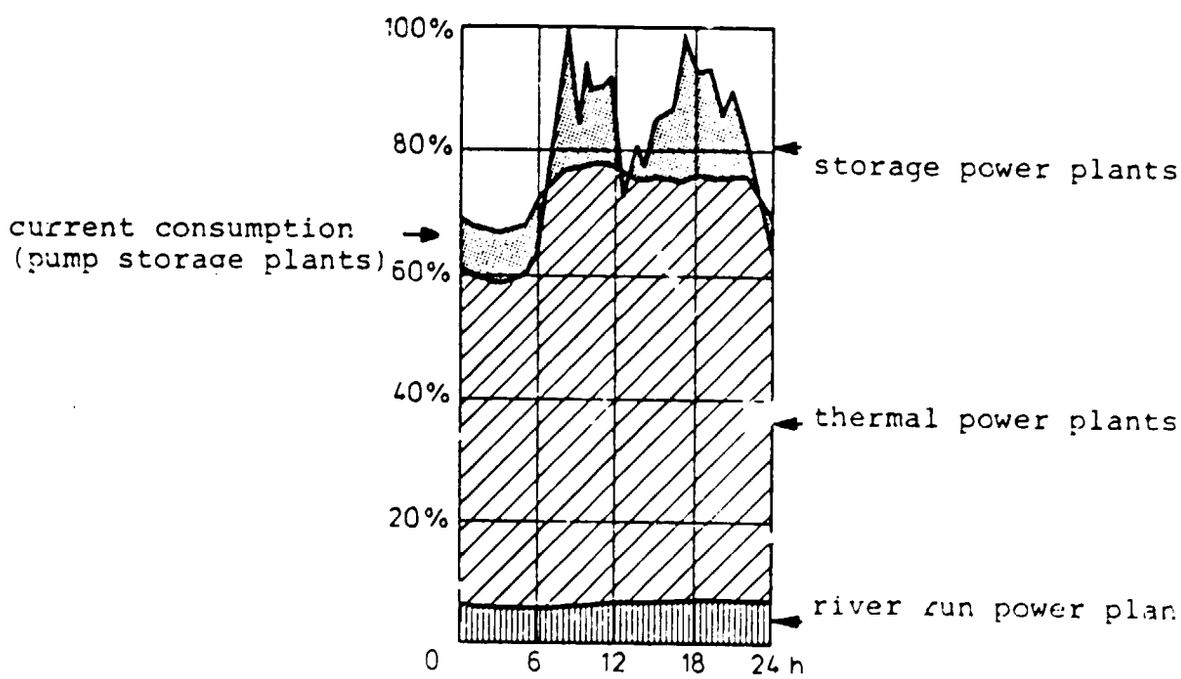


Fig.1 Consumption of electrical energy on a winter-working-d

Compensation of peak loads is mainly effected by pump storage plants, a type of power plant that has only been developed and constructed in the last few years. The reservoirs of these plants are now being constructed big enough to compensate apart from the daily variances in demand also for the weekly variances and even for a failure of thermal electric power plants up to a period of approx. 5 days.

River run power plants (see Figure 2) by which it is attempted to utilize all available energy according to the water supply and the existing height of fall are serving to provide the basic load. Compensation of peak loads by rise-operation of chain-type river run power plants is of local importance.

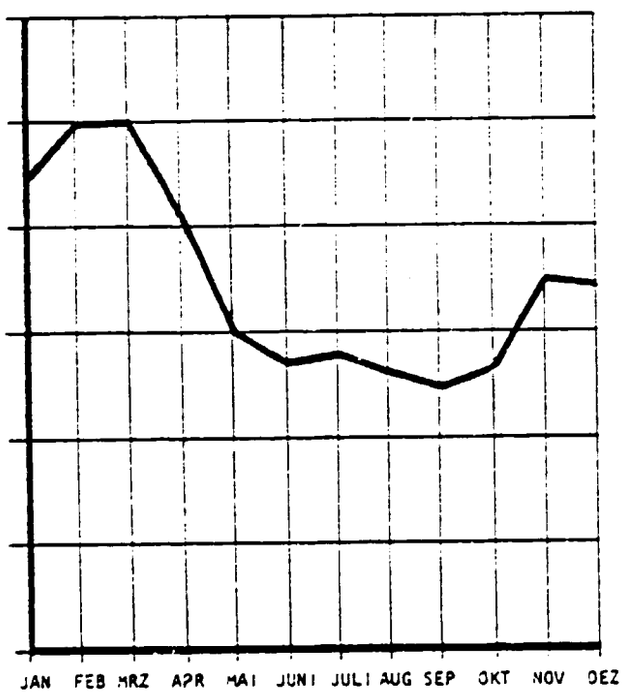


Fig.2 Average annual flow of a german river "Donau"

Also with regard to energy generation in general, mini hydro power plants - most of them being river run power plants - are ranging very low. For regional industrial development, however, they are rather important. Statistics for Germany are not available.

2. Historical development of water power utilization

The first utilization of running water for generating energy might date back as far as the invention of the wheel. River bucket wheels have been known in the Orient since the 7th/6th century B.C. The Romans developed a water wheel with horizontal shaft and toothed angular gear in the 1st century B.C. In the Middle Ages and with the beginning of modern times corn mills and hammer works were the most popular means of using energy generated by water wheels.

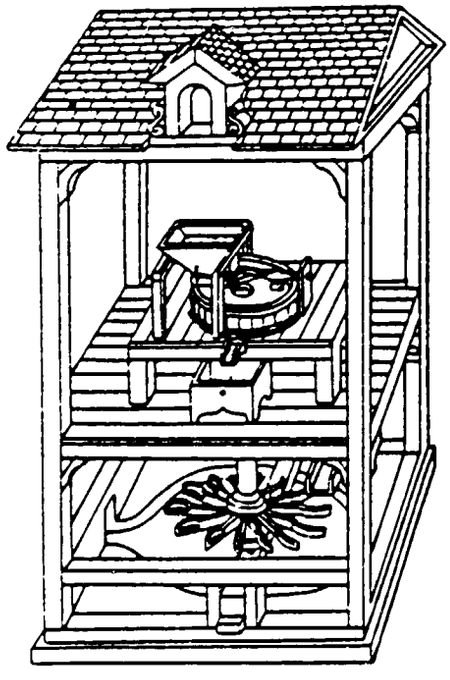


Fig.3 Mill and turbine wheel

In the 15th century the first horizontally positioned free jet turbine was constructed, enabling an improved utilization of water power. (The name 'turbine' appeared first in 1824. A French teacher called C. Burdin used it for his reaction engine. Since then all rapidly moving hydraulic engines are called turbines). Industrial utilization of water power started in 1848 with the development of the Francis turbine in the USA.

In 1875 the capacity of all hydro power plants in Germany amounted to 118 MW with an average capacity of 20 kW per plant. By 1895 this output had been doubled along with the rapid industrial development. The energy supply was in most cases transmitted mechanically and used for local consumption.

Utilization of water power for generating electrical energy became more popular after 1890, when the asynchronous alternator and the high-tension transformer were invented. Until to the outbreak of World War II the installation of turbines - especially of the small-size turbines - increased rapidly.

From 1910 on there was a stagnation in the harnessing of mini hydro power. The number of newly constructed plants decreased and repair works on existing plants were often omitted for cost reasons.

Instead, the big energy supply companies bought the water rights from owners of small plants and often they put the plants out of action. Electricity was more and more provided by steam power plants, which - with increasing demand - became amortizable within less time.

After 1920 it was started in Germany to harness large-scale water power. Turbines for the generation of electricity were installed on the weirs along with training works on the big rivers Rhine, Donau, Elbe, Oder, Main etc. From this time are dating the first networks interlinking various generating stations. By 1940 all big towns had been connected to the different local mains systems.

After World War II there was an increase in the utilization of water power, especially with large-scale plants.

At that time the generation of electrical energy by water power amounted to approx. 19% of the total energy output.

Until 1976, this quota decreased to 4.5%, still amounting to 13.3% in 1966. This was not only due to the increasing demand for energy in general but also to the closing of more than 1,300 (mostly small-type) corn mills which so far had been run with water power.

At present there are still approx. 500 large-scale and more than 10,000 small-scale hydro power plants in the Federal Republic of Germany, the large plants being owned by the supply companies and most of the small ones being run by private owners. Several experts estimated independently from each other that until 1985 the share of water power for generating electricity will decrease down to 1%.

Utilization of water power and river training

In the 19th century the utilization of water power in Germany was mainly effected by private owners of, for example, mills or sawmills. They had bought the rights for utilization of water power from the national government authorities.

Since the plants were of very small type and since they were adapted to the local conditions, there were only slight ecological changes caused by this interference with natural processes. On the other hand, there was in many cases a most positive development for the water resources. Bad erosion upstream to the retaining weirs could be stopped and further lowering of the subsoil water level could be prevented. Furthermore, cleaning of the river water was effected on the plant inlet trashrakes, and the water was partly enriched with oxygen at the water wheels and turbines.

Government authorities and local energy suppliers started in the beginning of the 20th century to train the rivers by means of large retaining weirs in order to prevent recurrent annual floodings and to produce low-cost electrical energy. Wide river valleys which up to that time had been flooded even by low water could now be cultivated for farming. Together with training there was very often a correction of the river course being made, the problematic consequences of which we still have to bear today.

Although the construction of big retaining weirs showed the desired useful effect, such strong interference with nature caused considerable disturbances in the existing ecological circulation systems.

Importance of mini hydro power plants

The decline of water power in the total energy output can only show that part of the significance of water as an energy source, which is calculable in terms of quantity. Important aspects of quality, however, are not taken into consideration, these lying mainly in the field of subsistence economy and supply of decentralized units.

From the historical point of view, in Germany the utilization of water power was the basis for development and growth of small industrial companies, especially in rural areas.

Fig.4 Shipmill

Wherever energy was required, water power was utilized first. In the beginning the company works were located next to the hydro power plants, since there was only

mechanical transmission of energy possible. After 1890, when electrical energy enabled a transmission over long distances, the various villages could be supplied, too.

A development of several branches of industry took place in the areas around the power plants. For this reason hydro power plants can be said to belong to the most important installations for infrastructural development of Germany.

From the statistical point of view the importance of mini hydro plants is at present rather negligible. Their real importance lies with the regulation of water resources and with the possibility of providing company works connected to them with low-cost energy.

For the government authorities, however, this is not reason enough to act against further closings of mini hydro plants or to offer financial aid for maintaining and overhauling existing plants.

3. The economic efficiency of mini hydro power plants

The economic efficiency of plants for generating energy depends on the general level of prices and especially on the prices of other energy sources.

The importance of water power was during the past 50 years diminished with the construction of steam power plants which were first heated with coal and later also with oil, too. After the recent increase of oil prices, hydro power plants are getting into the rehabilitation range more easily. Mini hydro power plants are subject to special conditions in this context.

The effect of economics-of-scales can also be observed with hydro power plants, i.e., the costs per installed kW will be reduced along with the increase in size. This applies both for turbines and for construction works of plants.

Still, as regards the economical aspects, mini hydro power plants are working profitable. This is mainly due to

- simplified construction of weirs
- adaption to environmental conditions
- investment of ownership capital.

In most cases economic efficiency is provided if the generated electricity is being used by the owner companies themselves. However, if the mini hydro plants feed a network interlinking various generating stations this network being provided by local energy companies, the generation of energy might often be uneconomical for reason of the disadvantageous contracts made with such supply companies.

Also seen from the position of national economy, a quantifiable estimate of the efficiency of mini hydro power plants can be made. When feeding the interlinking network, they are providing approx. 51% of their long-term annual average as a guaranteed output. Temporary failure of a mini hydro power plant will not cause any difficulties with the interlinking network, and as well there will be no expensive provisions necessary for replacement supply.

In addition, the costs for supply networks are being reduced because feed lines to the consumers are becoming less expensive.

Another favourable argument in national economy is the utilization of water in general, being a regenerative energy source which is not depending upon international currency exchange rates.

Taking all these economic arguments into consideration, it is recommendable to utilize water power potentials, especially small-scale hydro power.

II. The situation of mini hydro power plants

1. Existence, construction and conditions of mini hydro power plants

Location and planning

Most of the mini hydro power plants are located on small rivers, either being diversion plants or river run plants. They are located at such places where water power has ever before been utilized. Especially in the foreland of the Alps mini hydro plants are being used for the utilization of small water quantities with very high falls. These plants have in common that there is only seldom a reservoir under management belonging to them.

The conditions these plants are in, differ to a large extent. Some of these plants have been shut down and have fallen to ruin, some are being run without maintenance until they fall to ruin, too. Part of them, however, are being overhauled and repaired and are - after modernization - in good condition. New construction of mini hydro plants is not being planned very often. If so, it is only being done at places where water power has been used before. Construction works are at present limited to overhauling and modernization especially of the plant weirs, always trying to achieve optimum utilization of existing energy sources.

Lately some new locations have been found for the erection of mini hydro power plants, following the desire to save energy. For instance, so-called compensating turbines have been installed at the end of long distance water supply lines, to compensate the remaining pressure energy which has not been used. (see Figure 5)

Such recovery of energy is given much consideration in all fields. This applies also for places where even low water potentials are utilized by means of structural alterations made, for example, at the different annexed plants of dams (entry storage basins, delivery lines, bottom outlets and partly also at spillways).

For an economical construction and operation of the above plants it is important to have an exact calculation of the designed capacity. For many plants this is difficult since there are often not enough measuring data available or - like with long distance water supply lines - the exact quantities taken by the consumers are not known.

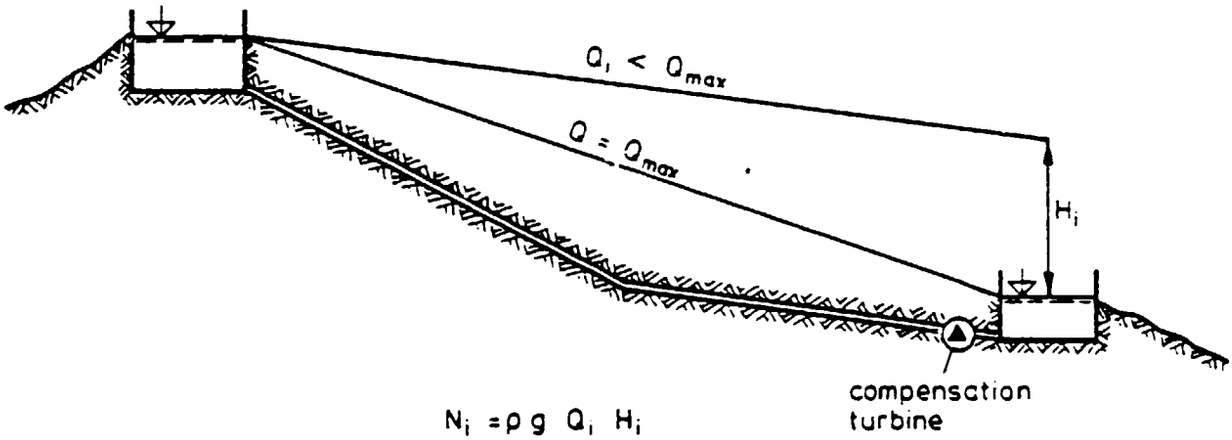


Fig.5 Hydraulic System of a long distance water supply line

Building construction

Reconstruction and new construction of old weirs, some of which are solid-type weirs and some of which can be regulated by means of boards and stop planks and reconstruction works on the station building themselves which became necessary with installation of new machines, are the most frequent modernizing works. With the old small-type high-pressure plants the pressure lines often have to be repaired and if possible have to be provided with a smooth inner lining.

Investment costs for complete new constructions of mini hydro plants (including machines) are at present amounting to 5,000 - 10,000 DM/kW for low-pressure plants and 3,000 - 7,000 DM/kW for high-pressure plants.

Not much progress hat yet been made with efforts to reduce costs by means of standardization of construction parts.

Turbines

Many of the old existing turbines are having a low efficiency. Therefore, modernization plans for mini hydro plants often include the installation of a new turbine.

The Mitchell-Ossberger cross flow turbine holds a leading position in the market, although other turbines designed for large-scale hydro plants can also be used - with slight simplifications - for installation in mini hydro plants. This is mainly due to the high effect achieved by restricted and medium water supply. If desired, this turbine can be delivered completely with generator and regulator, mounted on a foundation frame.

At present the turbine manufacturers are trying to reduce the prices of small-size turbines by standardization and thereby to hold and expand their position in the market.

Generators

For the range of up to 200 kW connection of almost all mini hydro plants to interlinking networks has led to an increased use of asynchronous alternators, being less complicated in operation, while for higher capacities the energy supply companies require synchronous alternators implying higher cost and labour for regulation.

2. Operation of mini hydro power plants

The plants still being in operation have meanwhile - as far as they are still family-owned - partly been adapted to semi-automatic operation and the tendency is leading to fully-automatic operation.

The mini type semi-automatic plants require for operation and maintenance a time of approx. 2 hours per day, while the fully-automatic plants only need a one-week overhauling time per year.

III. The future development of mini hydro power plants

For an estimation of the future development of mini hydro power plants, not only business data and political economy must be taken into consideration but also the interests of environment protection and water resources. According to estimates given by experts, the following development is to be expected with regard to economic efficiency:

- Micro hydro power plants up to 10 kW will be continually shut down.
- Mini hydro power plants up to 100 kW will continue to exist under family ownership, provided that no high-cost repair work is required.
- Mini hydro power plants up to 1000 kW will continue to operate with economic efficiency if they are fully automized.
- For mini and medium hydro power plants from 1000 kW on a new construction will in most cases be profitable.

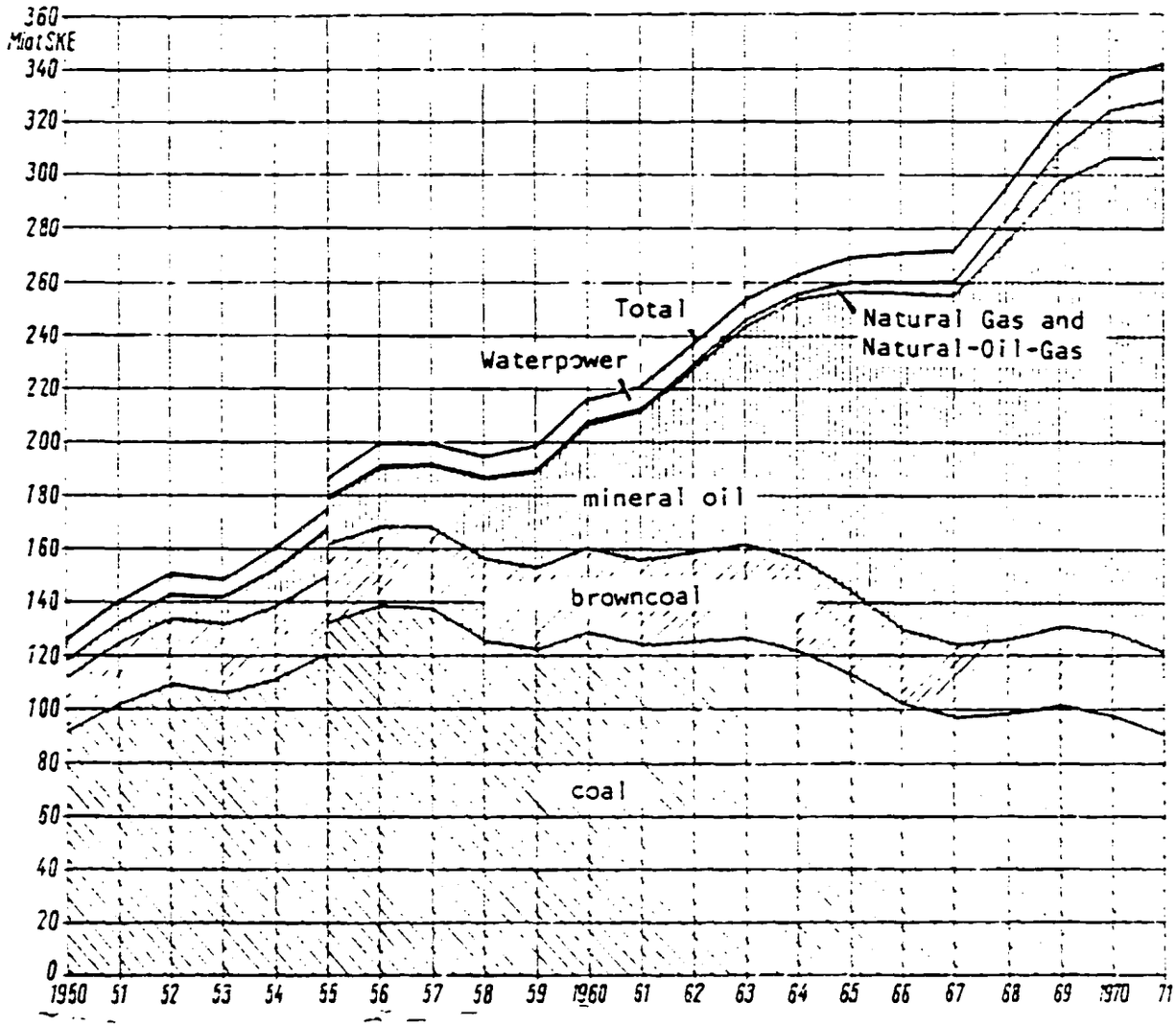
However, considering not only the economical but also the other above stated arguments, maintaining of all mini hydro power plants is desirable.

A close look to the activities which at present are taking place on the energy sector, this aim seems to be not too far away. For example, increased efforts can be observed on the side of private owners to modernize their plants. As well, industry and consultants have shown new interest, mainly with regard to expected trade and cooperation with developing countries.

As well, research institutes and government authorities dealing with the cooperation with developing countries, intend to give a new priority to mini hydro power plants.

It might be expected that all this will make such plants to remain an important and essential part of our environment.

Appendix 1



Pict. 1 Consumption of primary energy in west Germany

Vereinigung Industrieller Kraftwerke (VIK)
Statistik der Energiewirtschaft Essen 1972