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# THE ENERGY REQUIREMENTS DUE TO WATER POLLUTION ABATEMENT

## 1. INTRODUCTION

In this time of energy conservation, it is not more than natural to look at every category of energy consumption and see what can be done to reduce the demand. On a national level, the most attractive categories to take a close look at are the ones consuming a significant portion of the energy available in this country. An EPA publication gives a good summary of the major energy consuming categories [1].

Apparently the total energy consumption in the U. S. was about $72 \times 10^{15}$ BTU/year in 1972. The per capita energy consumption was at that time about $350 \times 10^{6}$ BTU/year. A breakdown of this total figure in the major categories consuming energy is"

Industrial — 29%,
Household, commercial — 20%,
Transportation — 25%,
Electricity generation
Utilities — 25%.

One of the fastest growing energy demands is for electrical power. From 150 to 1972, the generation of electricity went up by a factor of about 3.5, from about 5.2 to $18.7 \times 10^{15}$ (quadrillion) BTU' s/year.

There are hundreds of uses for energy, but only a relatively few account for the major portion of the nation's total energy consumption. Table 1 summarizes the major end uses for energy.

In the same article, the author puts the energy requirement for pollution control in perspective with total national demands. There are four main categories of environmental control that will make a demand on its share of the national energy pie. These are:

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Table 1

Major end uses for energy, 1968 data

| Type of use | Percent of total U.S energy consumption |
|---|---|
| Transportation (fuel; excludes lubes and greases) | 24.9 |
| Space heating (residential, commercial) | 17.9 |
| Process steam* (industrial) | 16.7 |
| Direct heat* (industrial) | 11.5 |
| Electric drive (industrial) | 7.9 |
| Feedstocks, raw materials (commercial industrial, transportation) | 5.5 |
| Water heating (residential, commercial) | 4.0 |
| Air conditioning (residential, commercial) | 2.5 |
| Refrigeration (residential, commercial) | 2.2 |
| Lighting (residential, commercial) | 1.5 |
| Cooking (residential, commercial) | 1.3 |
| Electrolytic processes (industrial) | 1.2 |
| Total | 97.1 |

* Includes some use for space heating, probably enough to bring total space heating to about 20 percent.

1. Emission Control for automobiles;
2. $SO_2$ control for power plants;
3. Wastewater Treatment;
4. Solid Waste Collection and Disposal.

It is anticipated that emission control on automobiles initially will reduce the efficiency of the motors, but that in the near future, this effect could be overcome by the design of more efficient cars.

The total energy requirement for $SO_2$ control on every power plant in the country could vary from 62 to 490 trillion BTU/year, depending on the choice of scrubbing device.

The energy requirement for municipal wastewater treatment is also not exhorbitant if compared with figures on a national level. If the total population would be served by tertiary treatment, the energy consumption would approximate 182 trillion BTU's per year or 0.25 percent of the total national energy demand. An estimate including industrial wastewater treatment arrives at a total energy requirement of 290 trillion BTU's per year.

The energy requirements for solid waste disposal are estimated to be 75 trillion BTU/year. This figure includes the transportation of all municipal and industrial solid waste to landfills.

In summary, a cleaner environment would increase the energy consumption in this country with only about 1%. It seems therefore that we can afford a clean environment as far as its impact on the national energy demand is concerned.

On an individual basis, however, the picture can be quite different. A lot of industries are confronted with simply the unavailability of more energy and therefore any energy for pollution control can only be made available by cutting the supply somewhere else.

This paper will outline the energy requirements for waste treatment systems with different flow rates and an increasing complexity of the treatment system. The data presented are based on work Lancy did for the National Commission on Water Quality [2]. The purpose of that study was to determine the cost and energy requirements for the metal finishing industry for meeting the effluent quidelines as specified by EPA for BPT and BAT*.

After presenting the energy requirements of some typical sized plants, the data will be extrapolated to the total energy requirement for the metal finishing industry to meet the effluent levels as promulgated by EPA.

## 2. ENERGY REQUIREMENTS FOR WASTE WATER TREATMENT SYSTEMS

### A. TREATMENT SCHEMES CONSIDERED

In the aforementioned study for the NCWQ, the cost data for waste treatment plants were arrived at by selecting seven models of typical metal finishing plants. For this discussion, the details on the seven models are irrelevant. Each had a series of metal finishing processes that resulted in a certain amount of wastewater that had to be treated. Each plant had several types of rinse water so that some degree of segregation was required in order to meet the effluent criteria.

The most elementary treatment scheme considered will be as shown in figure 1. The different types of rinse water will have to be transferred to the treatment plant. It is assumed here that this will require pumping stations. The first step for the different types of rinse water will be some type of chemical treatment. The energy consuming items in this step are only some mixers. The chemical feed will consist of a series of chemical supply tanks, each equipped with a chemical feed pump and a mixer only to be used during chemical make-up.

The next step is to flocculate the combined rinse water stream prior to clarification. The energy-consuming pieces of equipment in these two unit operations are flocculator, agitator, mechanical drive in clarifier (if unit is large enough) and sludge pumps.

The overflow from the clarifier is assumed to flow by gravity into the sewer or river. The sludge blowdown from the clarifier will be pumped to the sludge handling facilities. For small plants, this will be merely a few batch sludge thickening tanks, while for the larger plants, this can include a sludge dewatering device.

In the data that will be presented in this paper, it is assumed that the spent process baths are batch treated separately from the rinse water. This is generally a preferable method of treatment above bleeding the concentrated wastes into the rinse water stream. From an energy point of view, the two treatment approaches will not make much difference

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*EPA set two deadlines to be met by key industries: the best practicable treatment (BTP) 1977, and the best available treatment technology (BAT) 1983.

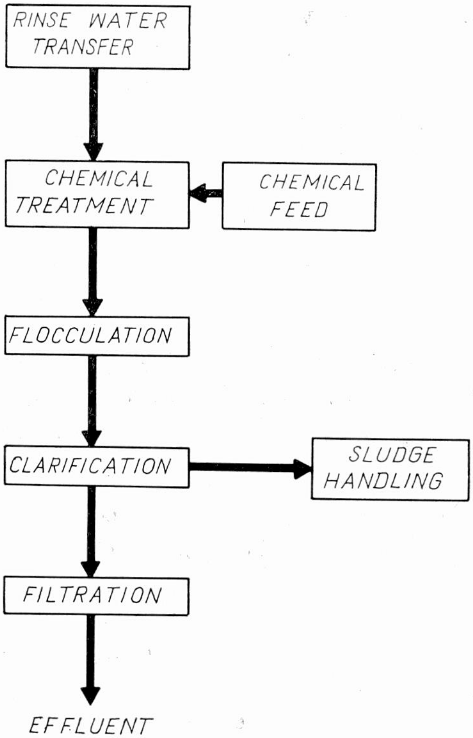


Fig. 1

in the actual energy consumption. The installed power will increase with batch treatment because of mixers and pumps, but it will be used only a few hours per week and therefore has no significant effect on the annual energy consumption for waste treatment.

In fig. 2, the effluent from the clarifier is filtered in a mixed media filter. This type of filter will require a collection sump to have an inventory of treated water to be used during backwash of the filter. The energy requirement of such a system is rather small; the only energy used is for the backwash pump. For smaller plants, cartridge-type filters could be considered. The use of these types of filter will require more energy since the water has to be pumped through the cartridges. The energy requirements still are relatively small and therefore the selection of a filtration system should be based on the merits of providing consistently a clear effluent and capital cost rather than on energy consumption alone.

The effluent from the filter should be good enough for partial reuse within the plant in non-critical rinsing applications. This energy requirement will be included in the data presented.

In order to increase the reuse potential of the rinse water, it becomes essential to keep the spent process solutions out of the rinse water. In this way, the TDS in the rinse water is kept low.

In fig. 3, the effluent from the filter is treated by reverse osmosis. This will require a pre-

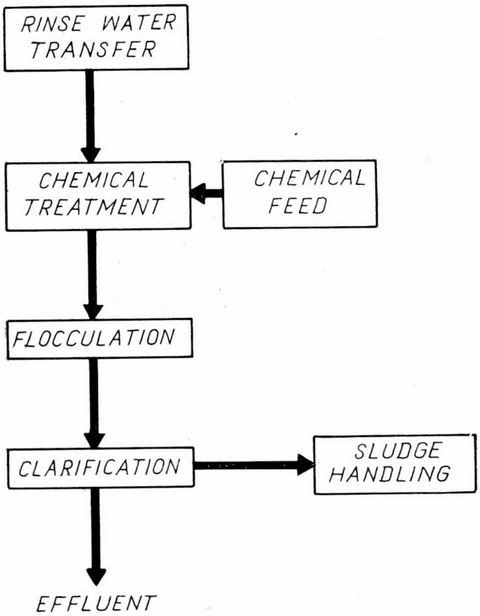
RINSE WATER TRANSFER
CHEMICAL TREATMENT
CHEMICAL FEED
FLOCCULATION
CLARIFICATION
SLUDGE HANDLING
EFFLUENT

Fig. 2

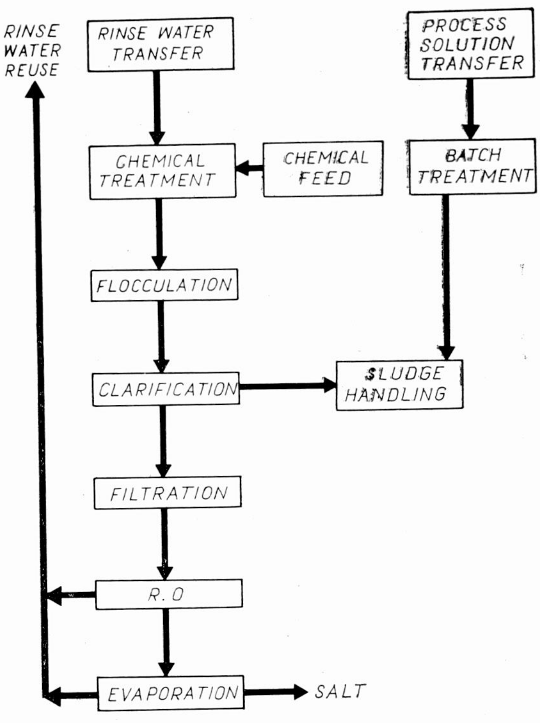
RINSE WATER REUSE
RINSE WATER TRANSFER
PROCESS SOLUTION TRANSFER
CHEMICAL TREATMENT
CHEMICAL FEED
BATCH TREATMENT
FLOCCULATION
CLARIFICATION
SLUDGE HANDLING
FILTRATION
R. O
EVAPORATION
SALT

Fig. 3

treatment step consisting of pH adjustment and cartridge filtration. The reverse osmosis system requires a significant amount of electrical energy to operate the booster pumps to reach a pressure of about 400 psi. It is therefore essential to keep the size of the system as small as possible. In the first place, try to recirculate as much water as possible ahead of the reverse osmosis (R. O.) unit. The feed to the R. O. should be water that would be the blowdown from a recirculated rinse water system.

In this scheme it is absolutely necessary to keep the concentrated solutions out of the system. The concentrate from the R.O. unit, together with the treated process solutions, will form the effluent from this plant.

The scheme (fig. 4) represents the treatment scheme that will be required if the plant has to meet "zero discharge". The effluent in scheme (fig. 3), which is a high total disol-

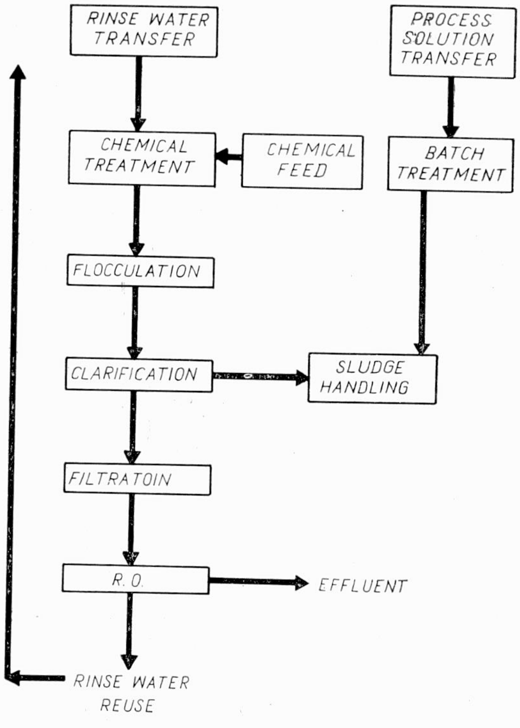


Fig. 4

ved solids (TDS) — containing stream is fed to an evaporator for concentrating the salt to a relatively dry mass. Since evaporation of water is a very high energy-consuming process, the flow to the evaporators should be kept to an absolute minimum. This minimum flow can be calculated by adding the total volume of the spent process solutions to the premeate of reverse osmosis unit at a concentrations of about 10 to 20 g/dm$^3$.

## B. ENERGY CONSUMPTION OF THE TREATMENT SCHEMES

The seven selected models varied with respect to rinse water flow rate, chemical consumption and type of metal finishing processes performed. The models were based on operating characteristics of existing plants. For each model, several treatment systems were designed to meet different effluent guidelines. The simplest treatment system considered here is as shown for fig. 1, while the most complex system is as shown for scheme (fig. 4). The energy requirements for the four schemes are summarized in the following. It is to be expected that the best correlation for a characteristic parameter of the models with the horsepower (HP) installed and energy consumption will be the rinse water flow rate

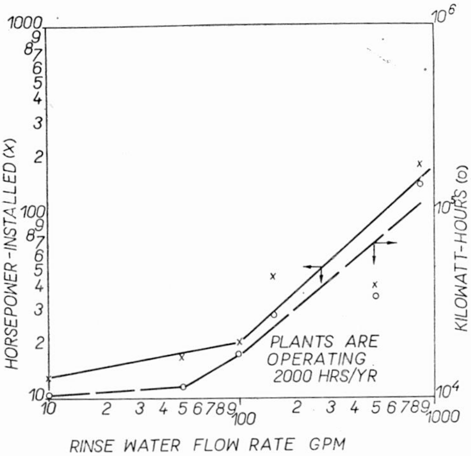


Fig. 5. Energy consumption (Scheme I)

Rys. 5. Zużycie energii (Schemat I)

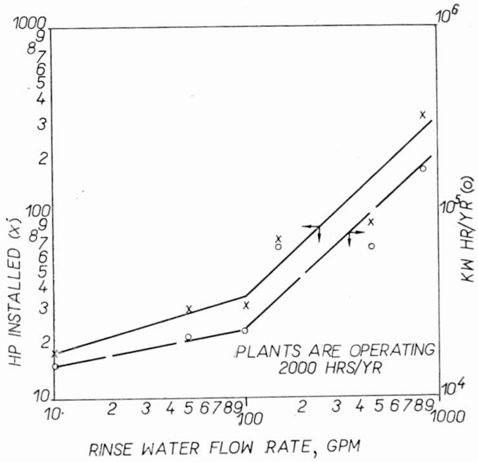


Fig. 6. Energy consumption (Scheme II)

Rys. 6. Zużycie energii (Schemat II)

to the treatment plant. At least this should be true for schemes (figs. 1 and 2), which sizing of the equipment solely depends on water flow. The important parameter for scheme (fig. 7) will be the flow to the R. O. unit, but this flow rate is in turn dependent on the chemical consumption. The input to the RO unit should have a TDS of at least 1 to 2 g/dcm$^3$ in order to make full utilization of the equipment. Any lower TDS input will indicate that water probably could be reused without being put through the R. O. unit. By reusing a part of the water after filtration, the size of the R. O. unit will be reduced and therefore the energy consumption. In general, however, there is in most plants a variable fraction that can be recirculated, depending on the quality requirements for the rinse water. Evaluating the data, it became clear that total rinse water flow rate was about as good a parameter as chemical consumption and is therefore used in this paper.

The determining parameter for sizing the evaporator in fig. 8 is the chemical consumption. The concentrated solutions will be sent directly to the evaporator, while the salts in the rinse water should be concentrated to the maximum possible extent with R. O.

Studying the curves for schemes (fig. 5 and 6), one can make the following observations:

1. The curves have two distinct sections. The treatment plants designed for flow rates of 10, 50, and 100 GPM(55, 275 and 550 $m^3/d$) will vary hardly in the HP installed because of the minimum sizes used for agitators and pumps in these systems. Above 100 GPM (550 $m^3/d$), the treatment system is more custom-designed and the energy consumption should be more or less dependent on the rinse water flow rate. The individual requirements for a plant can vary, however, quite considerably. This is exemplified by the two models with a flow rate of 150 and 500 GPM (825 and 2750 $m^3/d$). Both plants have approximately the same energy requirements. The main reason for this is the fact that the 150 GPM (825 $m^3/d$) plant

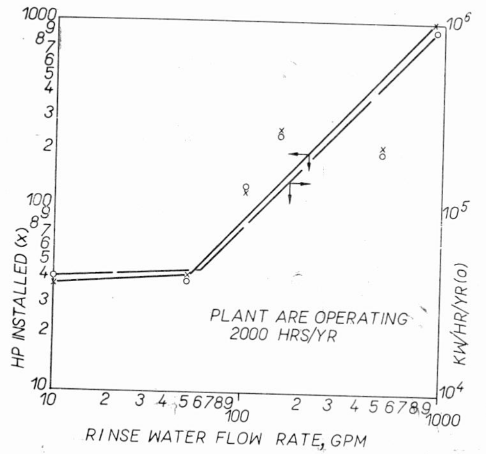


Fig. 7. Energy consumption (Scheme III)
Rys. 7. Zużycie energii (Schemat III)

has a centrifuge for dewatering the sludge generated. This plant has a lot of bright dipping with phosphoric acid and generates about three times as much sludge as the plant with a flow rate of 500 GPM (2750 $m^3/d$) .This higher sludge production will justify the installation of a dewatering device. Therefore, the figures for the 150 GPM (825 $m^3/d$) plant will be on the high side of the range, while those for the 500 GPM 2750 $m^3/d$ will be on the low side.

The treatment plant designed for the 850 GPM (3850 $m^3/d$) plant also includes a dewatering device. Also, this plant has to pump its water from several locations to a centralized treatment plant. Therefore, the energy cost for this model will also be on the high side of the range.

2. Adding filtration at the end of the treatment system increases the installed HP by 75% on the average because of the relatively large backwash pumps and the partial recirculation of the rinse water. The actual energy consumption increases on the average by 50–100%. This figure will vary from plant, depending on the fraction of water that can be recirculated to the production area.

The installation of R. O. will drastically increase the power consumption of the plant. As can be seen from the curves for scheme in fig. 7, the installed HP has been increased by a factor of 2.5 until 6, while the power consumption increased by a factor of 4 until 8, compared to scheme in fig. 5. The increase in power consumption is higher than in HP installed because of the higher percentage of the installed HP that will be in operation full time. The rinse water flow rate shown in the figure is not the flow to the R. O. units. In four of the seven plants, the flow to the R. O. units could be reduced because of the potential to reuse part of the water after filtration. There will therefore be quite a variability in the power consumption from different plants because of this latter consideration.

The actual energy requirement of an R. O. unit is easily calculated. First, the flow has to be pumped through a cartridge filter, while the second step is to pump the water at the specified pressure (28 at). The minimum flow to the R. O. system can be calculated by assuming that water can be reused in most plants in non-critical rinses until a TDS of 1–2 g/dm$^3$ is reached, and that the input to the R. O. units should therefore have a TDS concentration of at least 1–2 g/dm$^3$.

The energy requirements will drastically increase when a plant would install a zero discharge system (fig. 4), for which the energy requirements are shown in figure 8. Again,

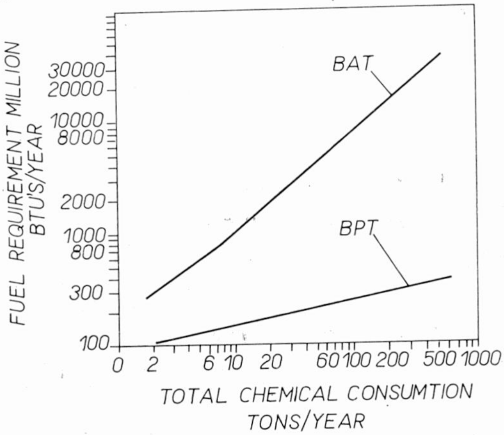


Fig. 8. Energy requirement for heating and evaporation
Rys. 8. Zapotrzebowanie na energię do ogrzewania i odparowania

a plant should do everything possible to reduce the flow rate to the evaporator. The concentrated process solutions should be sent undiluted to the evaporator, while R. O. should be employed to get the salt in the rinse water as concentrated as possible. Figure 8 shows the heating requirements for plants with different chemical consumptions for two pollution abatement levels. The heat required for the systems discussed up to this point is only that necessary for heating the waste treatment building. This in general should be small compared to the overall heating requirement of plants since the waste treatment plant normally is small compared to the rest of the plant. Evaporation of salty water changes the heating requirements drastically. For example, the plant with a flow rate of 150 GPM (825 m$^3$/d) had a total chemical consumption (including chemicals for waste treatment) of 120 tons/year. The energy requirements for evaporation would therefore be about

$7\times10^9$ BTU/year or $2.0\times10^6$ KWh/year. For scheme in fig. 3, this plant used $0.25\times10^6$ KWh/year. The plant with a flow rate of 500 GPM (2750 $m^3$/d) had a chemical consumption of 35 tons/year. The energy requirements for just evaporation are $0.7\times10^6$ KWh/year, while this plant used $0.2\times10^6$ KWh/year for scheme in fig. 3. The largest model included in this discussion uses $1\times10^6$ KWh/year for scheme in fig. 3 with a rinse water flow rate of 900 GPM (4125 $m^3$/d). The total chemical consumption of this plant is 1.500 tons/year and therefore the energy requirements just for evaporation is $13\times10^6$ KWh/year. For the smallest plant, the energy consumption for evaporation is $0.6\times10^6$ KWh/year (chemical consumption is 30 tons/year) while for scheme III, this plant used only $0.04\times10^6$ KWh/year.

### C. SUMMARY

Evaluating the data presented here, it is possible to obtain a ratio of the relative energy consumption for the different schemes. If for scheme I an energy unit of 1 is consumed, the other schemes would use the following number of energy units"

1. Scheme II 1.5–2,
2. Scheme III 4–8,
3. Scheme IV 16–104.

It should be remembered that these figures are minimum values which can only be obtained with the proper segregation and reuse of waste streams.

## 3. TOTAL ENERGY CONSUMPTION FOR METAL FINISHING INDUSTRY TO MEET EFFLUENT GUIDELINES

In the study performed for the NCWQ[2], and estimate was made of the total number and characteristic of plants involved in metal finishing in the U. S. For each category of plants, an average rinse water flow rate and chemical consumption was assumed. Based on the information collected with the models, the energy requirements for BPT and BAT were plotted versus the rinse water flow rate as shown in figure 9.

Figure 8 is used to determine the energy requirements for evaporation of the concentrated salt solution. Based on these data, an estimate was made for the metal finishing industry as a total for the energy requirments to meet BPT and BAT. Table 2 shows the results. The total energy requirement for BPT is $7.7\times10^9$ KWh/year for electrical energy and thermal energy for heating the waste treatment plants. For BAT, this figure is $35\times10^9$ KWh/year ($122\times10^{12}$) BTU/year for electrical energy and thermal energy for heating and evaporation. BAT will only have to be met by plants discharging directly to rivers. This explains that the increase in energy requirement for BAT is not as high as mentioned in section II.C for individual plants.

To provide a comparison, survery data presented by J. VOEGTLE [3] shows energy requirments for all publicly-owned sanitary treatment plants in the U. S. (including sludge drying and incineration, where applicable) to be $18 \times 10^9$ KWh/year and $3.7 \times 10^{12}$ BTU/ /year, or a total of $19.0 \times 10^9$ KWh/year ($67 \times 10^{12}$ BTU/year). This is supposed to increase until $51 \times 10^9$ KWh/year $182 \times 10^{12}$ BTU/year, if all sanitary wastewater treatment plants will adopt the tertiary treatment [1].

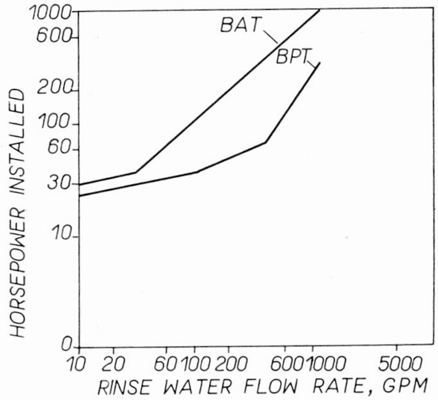


Fig. 9. Horsepower requirements for BPT and BAT

Rys. 9. Zapotrzebowanie mocy dla najlepszego ekonomicznie uzasadnionego procesu oczyszczania ścieków (BPT) i najlepszego pod względem technicznym procesu oczyszczania (BAT)

Table 2

Projected energy requirements

| | Electrical energy 10, KWh/year | Thermal energy $10^{12}$ BTU/year |
|---|---|---|
| Best Practicable Treatment Technology (BPT) | 4.1 | 12.3 |
| Best Available Treatment Technology (BAT) | 6.5 | 95 |

## ZAPOTRZEBOWANIE ENERGII NA CELE OCHRONY WÓD PRZED ZANIECZYSZCZENIEM

Na podstawie o globalnego zapotrzebowania energii dla różnych dziedzin gospodarki amerykańskiej przedstawiono zapotrzebowanie energii na cele oczyszczania ścieków przy różnym natężeniu przepływu i dla różnych schematów technologicznych. Praca miała na celu ustalenie kosztów i zużycia energii, niezbędnych dla uporządkowania gospodarki ściekowej w przemyśle galwanizerskim, przy zapewnieniu najlepszego ekonomicznie uzasadnionego procesu oczyszczania ścieków (tzw. BPT) do roku 1977 i najlepszego pod względem technologicznym procesu oczyszczania (tzw. BAT — bez uwzględniania aspektów ekonomicznych) do roku 1983.

## ENERGIEBEDARF ZUR REINHALTUNG DER GEWÄSSER

Anhand des globalen Energiebedarfs in verschiedenen Zweigen der amerikanischen Wirtschaft, wird dieser Bedarf für die Abwasserreinigung in Kläranlagen verschiedener Kapazität und mit unterschiedlichen Reinigungsverfahren dargestellt. Der Beitrag hatte zum Ziel, die Berechnung der Kosten und des Energiebedarfs für eine Ordnung der Abwasserwirtschaft in der Galvanik-Industrie bei Beihaltung des bestmöglichen, ökonomisch begründeten Prozeßes (BPT) bis zum Jahre 1977 und des bestmöglichen, technologischen Verfahrens bis zum Jahre 1983 (BAT); im zweiten Fall ohne Berücksichtigung der ökonomischen Gesichtspunkte.

## ПОТРЕБНОСТЬ В ЭНЕРГИИ ДЛЯ ЗАЩИТЫ ВОДЫ ОТ ЗАГРЯЗНЕНИЙ

На основе общего затребования энергии для различных отраслей американской экономики представлено затребование энергии для очистки сточных вод при различной интенсивности течения и для различных технологических схем. Цель работы заключалась в определении издержек и потребления энергии, необходимых для того, чтобы привести в порядок водосточное хозяйство в гальванической промышленности с обеспечением экономически обоснованного процесса очистки сточных вод до 1977 г. и наилучшего в технологическом отношении процесса очистки до 1983 г.

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