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EXPECTED DEVELOPMENT OF CHEMICAL POWER SOURCES

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1. Introduction

Research in chemical power sources has progressed appreciably as a result of considerable material and mental investment in the improvement of the specific characteristics of applied power sources during the last 25 - 30 years.

Taking this into consideration, we have to admit that wide-ranging practical application of fundamentally new power source systems has not taken place either in the field of accumulators or in that of fuel cells.

The most important development has taken place in the field of primary elements, where elements using the lithium electrode have come into general use much more quickly than was expected. This fact forces the developers to investigate the technical and economic requirements, the fulfilment of which makes successful research possible and promotes the selection of the production-ready constructions.

Taking into consideration that the technical requirements and different points of view have already been investigated many times by a number of researchers, the aim of the present work is to try to investigate the different power sources from the point of view of the user groups and then to predict the trends in development.

2. Possibilities according to users' requirements

Consumers can be divided into two main groups: (1) professional consumers, institutions and organizations; (2) non-professional and domestic consumers.

In the case of professional consumers, workers having some standard of training are available to obtain and handle power sources and some minimum maintenance standards can be required of them. For selection and purchase, a certain knowledge of the items and their technical parameters can be expected. Their selection will depend on the following requirements, probably in the order given:

(a) technical: loadability (W/kg), weight (W h/kg), life (cycle numbers or years);

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(b) economic: purchase price (\$/W h), operating price (\$/W h cycle);

(c) convenience: maintenance requirements, reliability.

In the case of non-professional consumers the order of importance changes fundamentally. One cannot expect the consumer to possess special knowledge. As a power source is never bought for its own sake but for the operation of equipment, it must not be either too expensive or too delicate. It is not generally desirable that it should be handled by the customer. Any new current source is used if these points are taken into consideration by the manufacturer. The customer will probably list his requirements in the following order:

(a) economic: mainly purchase price;

(b) convenience: mainly maintenance-free;

(c) technical: perhaps for certain groups of customers.

Taking into consideration the above-mentioned points of view I have tried to give some technical prognosis for single power sources, but this may be defective and may be modified considerably by new research.

3. Investigation of single power sources

I have tried to evaluate single power sources on the basis of the known data as 'satisfactory', 'mediocre', 'good' or 'excellent'. The evaluation is subjective and I have only tried to put forward comparative values in order to arrive at some sort of appreciation of the various sources.

3.1. Accumulators in present use

Lead–acid accumulators

Technical requirements:

Energy density	35 - 40 W h/kg
Power density	50 - 100 W/kg
Lifetime	200 - 2000 cycles
Evaluation	Good

Economic properties:

Price	0.1 - 0.4 \$/W h
Operating price	0.1 - 0.3 \$/kW h per cycle
Evaluation	Excellent

Convenience:

Storage quality and resistance to overfilling and deep discharge are mediocre. Generally needs maintenance.

Evaluation	Mediocre

Prognosis:

Expected to remain in professional and private use, and may be more widely employed in the next 10 - 15 years.

Ni–Cd accumulators

Technical properties:

Energy density	15 - 35 W h/kg
Power density	100 - 300 W/kg
Lifetime	500 - 2000 cycles
Evaluation	Good

Economic properties:

Purchase price	0.9 - 1.2 $/W h
Operating price	0.5 - 1.5 $/kW h
Evaluation	Good

Convenience:

Insensitive to storage, overcharge and deep discharge.

Evaluation	Excellent

Prognosis:

Expected to remain mainly in professional use and to be employed a little more in future.

Ni–Fe accumulators

Technical properties:

Energy density	40 - 60 W h/kg
Power density	40 - 140 W/kg
Lifetime	800 - 2000 cycles
Evaluation	Good

Economic properties:

Purchase price	0.6 - 1.0 $/W h
Operating price	0.4 - 2.0 $/kW h
Evaluation	Excellent

Convenience:

Insensitive to overcharge, deep discharge, and shaking.

Evaluation	Excellent

Prognosis:

Produced at present in large quantities in the Soviet Union. Can be expected to spread into the fields of application of lead–acid and Ni–Cd accumulators, and to be employed by both professional and private users.

3.2. Other and prospective accumulators

Ni–Zn accumulators

Technical properties:

Energy density	60 - 70 W h/kg
Lifetime	200 cycles
Evaluation	Mediocre

Economic properties:	
Purchase price	0.6 - 1.1 \$/W h
Evaluation	Mediocre
Convenience:	
Evaluation	Good

Prognosis:

Technical and lifetime problems inhibit an increase in its use within the next 5 years.

Ag–Zn accumulators

Technical properties:	
Energy density	~100 W h/kg
Lifetime	~200 cycles
Evaluation	Mediocre
Economic properties:	
Purchase price	4 - 10 \$/W h
Evaluation	Satisfactory
Convenience:	
Evaluation	Good

Prognosis:

Because of its price and lifetime problems it recedes into the background, even for professional use.

Zn–Br system accumulators

Technical properties:	
Energy density	~150 W h/kg
Lifetime	250 - 500 cycles
Evaluation	Good
Economic properties:	
Evaluation	Excellent
Convenience:	
Evaluation	Good

Prognosis:

Not at present on the market. Economic conclusions are based on estimates from the developers only. On the basis of the above-mentioned data, can be used first for traction purposes. Probability of application in traditional current source fields is small.

3.3. Accumulators operating at high and average temperatures

The members of this group (Na–S, Li–FeS, etc.) are in the development stage at present, consequently the technical data and estimates are based on experimental results.

Technical properties:

Energy density	100 - 150 W h/kg
Evaluation	Good

Economic properties:

Evaluation	Excellent (according to developer)

Convenience:

Evaluation	Satisfactory

Prognosis:

Development has already been delayed because of material problems; practical application cannot be expected within 5 years. Useful only for traction purposes.

Other new systems (mainly the plastic accumulator) do not possess enough known properties to make a positive evaluation, but if they perform half as well as their developers hope, they can be employed by professional and private users, but considerable production cannot be expected within 5 years.

3.4. Primary elements

Leclanché cells

Technical properties:

Energy density	30 - 75 W h/kg
Storage time	0.5 - 2 years
Self-discharge	1% - 5% per month
Evaluation	Mediocre

Economic properties

Purchase price	0.2 $/W h
Evaluation	Good

Convenience:

Because of short storability and danger of leakage, can be used only in relatively unimportant places.

Evaluation	Mediocre

Prognosis:

A slow decrease in the field of application of these cells can be expected. Their complete replacement, particularly in private applications, is not likely to take place.

Alkali–manganese dioxide cells

Technical properties:

Energy density	70 - 85 W h/kg
Storage life	2 - 3 years
Self-discharge	0.1% - 1% per month
Evaluation	Good

Economic properties:

Purchase price	~ 0.3 - 0.4 \$/W h
Evaluation	Mediocre

Convenience:

Can be stored well; no danger of leakage.

Evaluation	Good

Prognosis:

Increased use of this type of cell can be expected, mainly in professional fields.

Elements with Li anode

Technical properties:

Energy density	~ 250 W h/kg
Storage life	5 - 8 years
Evaluation	Good

Economic properties:

Purchase price	2 - 3 \$/W h
Evaluation	Satisfactory

Convenience:

Can be stored; free of leakage problems.

Evaluation	Excellent

Prognosis:

Increasing application will take place in the private field, first of all in small sizes.

Fuel cells

At present these are still being developed and in certain cases they have been produced on an experimental level. The elements operating at low as well as high temperatures are complicated systems.

Technical requirements:	Mediocre - good
Economic properties:	Satisfactory - mediocre
Convenience:	Satisfactory - mediocre

Prognosis:

Use of low temperature elements for vehicle propulsion cannot be expected within 5 years; they can be applied in certain special fields.

Use of high temperature fuel cells is possible mainly for large scale applications; their widespread use is not expected. Each type of cell can be considered for professional use only, as the amount of associated equipment and the complicated system make its private use hopeless in the near future. Such a system must be simple, cheap and leakproof, and no prototype has been found to fulfil these requirements.

Metal–air elements

Among these elements the zinc–air types are the most developed.

Technical properties:	Good
Economic properties:	Mediocre
Convenience:	Mediocre

Prognosis:

A small increase can be expected in private and professional use of small size elements, mainly in the field of zinc anode cells.

4. General requirements regarding the future

According to the above-mentioned facts, present power sources will probably continue to be used for the next 5 - 10 years. Further development trends, taking into consideration the results achieved at present, will be as follows.

(1) In the case of commercial power sources used mainly for private purposes, the primary aim will be the further satisfaction of convenience and economy. The power sources made from inexpensive, readily available, non-hazardous and environmentally acceptable basic substances are produced by using essentially conventional materials (lead, carbon, lithium, iron, nickel, manganese oxide, etc.). Future development may be expected to take the form of increased use of new technologies, such as

production technologies using plastic bonding material for elements employing acid and alkaline electrolytes;

safer sealing technologies and materials in primary and secondary power sources, perhaps using plastics;

greater utilization of both active and passive materials (resulting in price reductions);

ecologically acceptable and recirculation technologies.

(2) In the case of power sources used for professional purposes, the technical requirements become more important. The power sources may also be in operation under extreme temperature and climatic conditions. The importance of lifetime and specific energy, as well as specific performance density, are increasing at the expense of the economic factors, because of the development of the following fields: power supplies for spaceships and satellites; power supplying systems, such as pacemakers, having medical uses; power supplies in military fields; continuous power supplying systems.

Many new fields of application appear to be possible, according to perhaps rather extreme claims: power supplies for electrical vehicles; operation of self-moving robot equipment; power supplies for large mechanical equipment for medical purposes (heart–lung motors).

In their present form, power sources are only suitable for these purposes to a limited degree. An increase in the ratio of power sources possessing alkaline electrolytes is expected for use as primary and secondary power sources because of the large power density claim. In addition to the more efficient use of the present power sources, new power sources and fuel cells under development will also come to the fore.

As well as the above trends in technological development, the following tendencies can also be taken into consideration: spreading of power sources containing moving component parts; application of elements containing electrolytes; use of biological batteries.

This short-term prognosis has considered only the possible application of power sources possessing the present, but improved, parameters.

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