emulsified within whatever oil was unabsorbed, or, becoming the external phase, is now the dispersing phase *for* this uncombined oil. The grease-producing activity of any soap is measured by its solvation capacity[1] wherein lies the explanation of the fact that science has discovered a whole series of metallic soaps superior to the older magnesium, calcium and barium compounds; and aluminium stearate being the cheapest of these, it today is the commonest of the soaps used in grease manufacture.

"Livering" in ready-to-use paints (especially the oil paints) represents a process analogous to grease formation.[2] Livering occurs whenever conditions are such as to allow of the formation of a solvatable colloid in the mixture which, becoming the solvent *for* the paint vehicle increases its viscosity, makes it semi-plastic or actually leads to its hardening.

Thus it comes about that certain paint mixtures (like the sulphides with linseed oil) never liver; others thicken an agreeable amount (as lead white with linseed oil on standing); still others liver to the point of spoilage. The latter is invariably the case where, with time, production of the heavier metal soaps comes about, which then, "dissolving" or "combining" with the paint vehicle, leads to solidification of the whole system. High content of free fatty acid, a definitely alkaline base and this of a nature to yield a soap highly solvatable—and intense livering is to be expected. For which reason the "lake colors" (especially those made by precipitating dyes upon aluminium hydroxide carry off the banner in this field.

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[2] MARTIN H. FISCHER and WERNER J. SUER: Kolloid-Zeitschr. **60**, 71 (1932); Lyophilic Colloids, 179, Charles C Thomas, Springfield, Ill. (1933).

HYDROGEN FOR THE OIL INDUSTRY

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UNTIL 25 years ago Hydrogen was almost exclusively used for the inflation of balloons and for high temperature work in the fabrication of metals. Only comparatively little was employed for strictly chemical work. Since then ever increasing amounts of Hydrogen have been needed for the Chemical Industries. First, for the hydrogenation of oils; since the beginning of the World War, for the technic in combining it with the nitrogen of the air to make ammonia, and also for the manufacturing of wetting agents for the Textile Industry through hydrogenation of coal tar compounds. During the last ten years, also the hydrogenation of coal and crude oil has been perfected.

In view of these developments it is interesting to compare the amounts of Hydrogen required for some of these processes.

Hydrogen required:	Cu. ft. (theoretically)
To inflate an airship (size of "Akron")	6,500,000
To produce 1 ton of:	
Ammonia, by catalytic process	63,000
Decalin, from naphthalene	28,000
Cyclohexanol, from phenol	22,500
To fully hydrogenate 1 ton of:	
Oleic acid	2,500
Linoleic acid	5,100
Linolenic acid	7,700
Coconut oil	285
Cottonseed oil	3,100
Soybean oil	3,350
To hydrogenate to consistency of lard (M. P. 98° F.):	
Cottonseed oil	1,300

When comparing the widely differing amounts necessary per ton of material, we realize that the problems of manufacturing hydrogen for the *different* industries must of necessity be manifold. We realize this even more fully on checking the total amounts of Hydrogen needed for some of these industries.

In 1932 the American Industries made daily about

1070 tons of [2]synthetic ammonia, requiring theoretically 74 million cu. ft. of H_2.

1000 tons of [3]hydrogenated oils* requiring theoretically 1.5 million cu. ft. of H_2.

Low cost and not the purity of the Hydrogen is of first importance for the synthetic ammonia industry, especially since nitrogen is needed for this reaction, and we find[4] that 60% of the Hydrogen needed in this process is supplied by means of the water gas process; only 13% is generated by electrolysis, f.i. in Italy, a country deficient in coal, and Canada, Sweden and Norway, where low hydro-electric power is abundant.

For the hardening of oils a Hydrogen of high purity is of great importance; in our country most of it is made according to the steam iron process. Steam passing at a high temperature over iron of a spongy character is decomposed into Hydrogen and at the same time the iron is oxidized. The oxide is regenerated and then used over again. The gas made by this process has a purity of over 99%; its only drawback is the fact that it contains a very small amount of carbon monoxide which is detrimental to the catalyst. In this respect we have to compare the amount of carbon monoxide with the amount of catalyst used in the reaction[5] and not with the oil or gas in order to clearly understand the significance of this impurity.

It is therefore not surprising that the general trend turned toward electrolytic gas which theoretically is 100% pure. This is noticeable especially in countries where large hydro-electric power plants supply cheap current or where coal and other fuel supplies are low priced.

To decompose water containing an electrolyte by electric current[6] a minimum voltage of 1.69 is needed with caustic soda or 1.67 with caustic potash. On practical operation voltages of from 1.9 to 2.5 are used to overcome the inner resistance of

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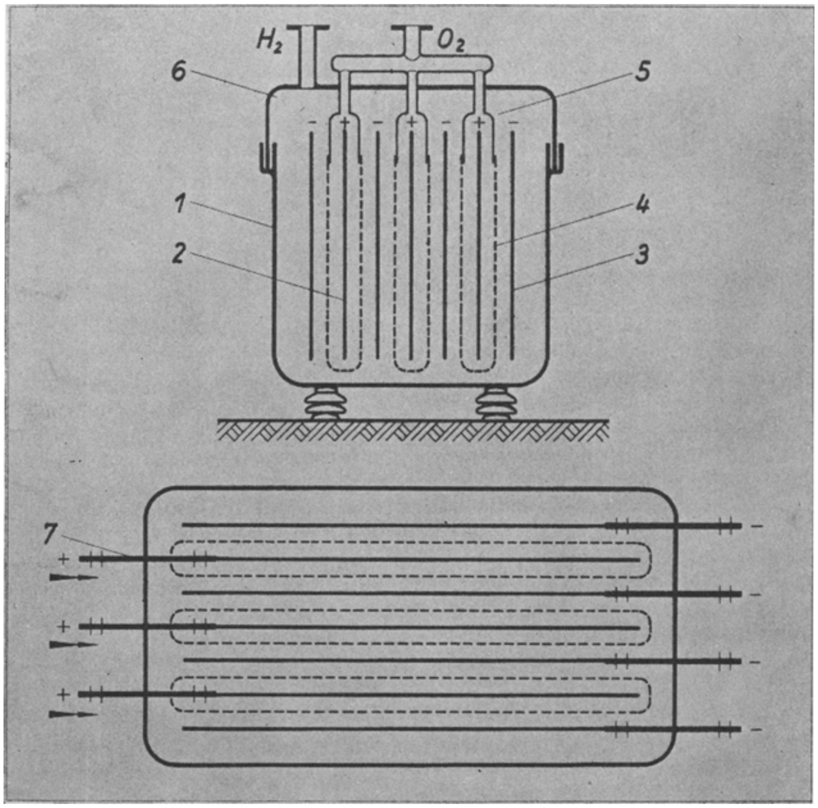
*Incidentally, the total amount of oils hydrogenated per year in the U. S. A. has not varied to any extent during the past year.

the cell depending on the construction features of the various systems. Theoretically, to produce 1,000 cu. ft. of Hydrogen of 32° F. and 760 mm. mercury, there are necessary 67,798 ampere hours. With a cell voltage of 2 volt, 136 KWH. produce 1,000 cu. ft. of Hydrogen.

The first cells used for this process were so-called trough cells, or unipolar cells, signifying the electric current distribution. They were developed by a number of engineers, as, f. i. Kent, Steward, Levin, Schuckert, Burdett, Fauser, Siri; the best known and most widely used in the U. S. A. is the Knowles cell.



The Knowles Cell

A number of electrode plates made of iron which may be nickel plated,—anodes (2) and cathodes (3) connected in parallel—are suspended in a steel trough (1) which rests on insulators. The diaphragms (4) between the electrodes, woven of asbestos, keep the generated gases apart. The electrolyte in the troughs consists of a solution of caustic soda or potash. The Hydrogen is collected in a bell (6) and the Oxygen is caught in headers (5) from where the gases are led off through properly insulated pipes. The seal of the bell may be wet or dry; the gas pressure amounts to up to 6 inches of water column. With a number of troughs arranged behind each other, the current connection from cell to cell is obtained by means of copper rails (7).

With plants of high capacity the gases have to be sucked off by means of exhaustors. Before entering the blowers, the gases have to be cooled. Plants of large capacity, requiring a large area, are in operation in Canada, France and Italy.

The efficiency of the unipolar cells has been brought up to a very high state. Its drawbacks are the large room requirements for the cells, extensive buildings, and, since the cells work at their best at a high temperature, the working conditions in a room where open cells are operated.

A more advanced type of construction was developed by Schmidt, Fauser, Shriver, Peckkranz and others and, during the past 10 years by Zdansky of the Bamag-Meguin Company of Berlin (Germany). This type, the so-called filter press battery differs fundamentally from the tank-type battery in having the individual cells connected in series and pressed together in the manner of filter press elements. Each electrode serves as anode on its one side and as cathode on the other, thus being of the bi-polar type. This system dispenses with the many current connections which are necessary with the unipolar batteries and the gases can be collected at any convenient low pressure.

It is obvious that, compared with the tank battery, the filter press type yields a greatly increased output, while, at the same time, it offers a considerable saving in space due to its very compact construction. Another important advantage is the fact that these filter press units can be cooled much easier and that the withdrawal of the gases is arranged in a much simpler way. Moreover, the cost of the filter press battery per unit of output is lower than that of the trough cells, since a large number of cells can be combined into one unit.

The first cells of this type were designed in accordance with figure No. 2, the cast iron electrodes (a) being interleaved with diaphragms (b) of asbestos fabric. To prevent leakage between frame and diaphragm, a rubber gasket (c) was vulcanized onto the outside rim of the diaphragm. This construction was found to be faulty as the rubber was attacked by the electrolyte and the nascent oxygen; the joint became leaky and the generated gases were impure. Furthermore, the electrodes corroded rapidly due to the full decomposition voltage of 2 volt between the adjacent electrodes.

To correct this fault, the cell voltage was split, as indicated in figure No. 3, by inserting the diaphragm (b) into a separate frame (d). By this means the gasket (c) was no longer exposed to the corroding influence of the decomposition volt-

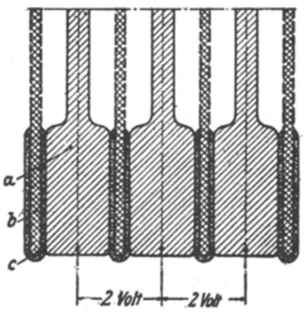


Fig. 2. Cell of the Filter-Press Type, Voltage Not Split.

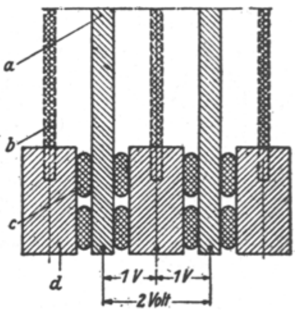


Fig. 3. Cell of the Filter-Press Type with Split Voltage.

age. Pechkranz was the first to introduce this construction; he also employed, instead of asbestos fabric, the first serviceable metallic diaphragm, nickel foil with an extremely large number of perforations, about 7,500 per square inch.

The Pechkranz battery was constructed as follows: some 100 or 120 circular electrodes, nickel plated on the anode side were assembled with interposed frames containing the nickel foil diaphragms, the whole forming a self-contained battery. Between the frames and the electrodes, asbestos cord impregnated with asphalt was placed. The battery was held together by tension bolts and end plates of heavy construction.

The Bamag battery of cells or Electrolyzer as designed by Zdansky embodies a number of improvements over the existing cells and therefore is deserving of special interest. When Bamag first became interested in Electrolyzers, about a dozen years ago, the different cells in use were studied mainly to find, and if possible to eliminate, their weak points. During their research they found how the current density per unit could be considerably increased. They changed the construction of the diaphragm which keeps the gases separated and, at the same time, should offer no resistance to the freely circulating electrolyte. Means were found to maintain the best working temperature and concentration of the electrolyte, and to insure the circulation so that fresh supplies of electrolyte are always forced to the electrodes.

Whereas the maximum current density permissible with the Pechkranz cell is about 93 amperes per square foot of electrode surface, the Bamag cell takes in as much as 230 amperes. This improvement was made possible by constructing an electrode of the type shown in figure No. 4, which consists of a main electrode (A) and two auxiliary electrodes (a1 and a2), arranged on either side and parallel with the main electrode. By means of a large number of connecting bolts the current is conducted to these auxiliary electrodes which are perforated so that the gases can be easily withdrawn from the zone of high action. Due to this construction the internal resistance of the cell is greatly reduced. In addition, the cathodes were formed in a novel way, similar to the electrode plates of an accumulator cell; this improvement allowed a considerable increase of current absorption without raising the voltage of the cell. Figure No. 5 shows the characteristic curves for various types of cells. As will be seen the Bamag Electrolyzer takes about 200 amperes per square foot of electrode surface at a tension of 2.1 volt, where other types at the same tension take only between 47 and 75 amperes. All these curves are plotted from plant results and may therefore be considered as practically correct.

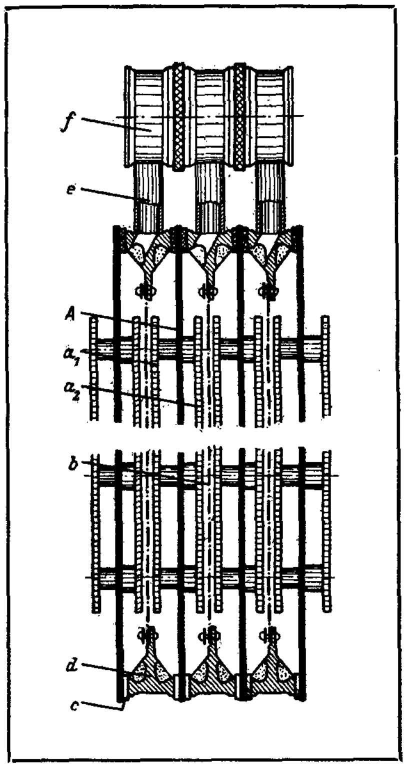


Fig. 4. Bamag Filter-Press Cell.

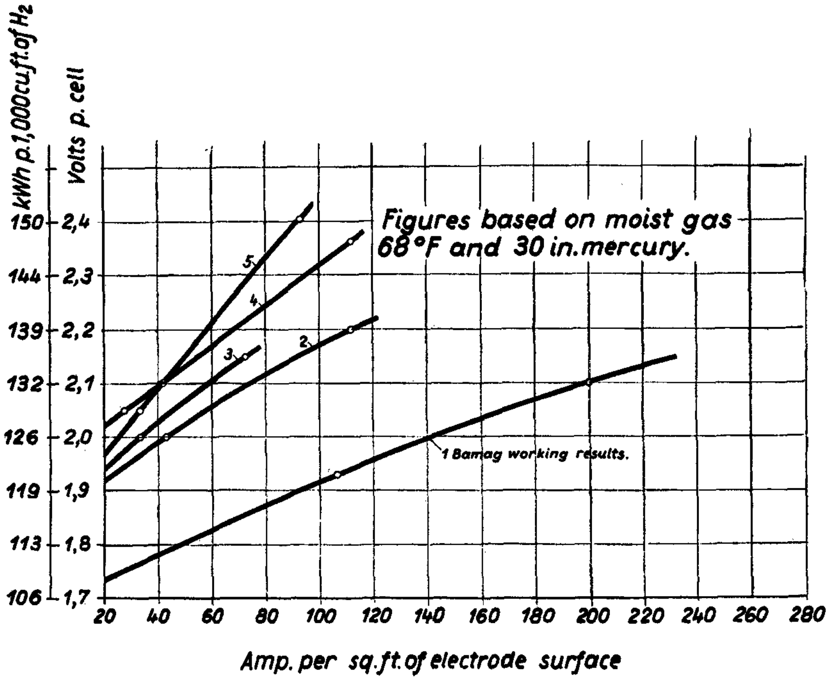


Fig. 5. Shows characteristic curves for various types of cells.

As the auxiliary electrodes are located fairly close to the diaphragm (see figure No. 4), the use of nickel foil had to be foregone to avoid the danger of short-circuit. Zdansky therefore reverted to asbestos fabric as diaphragm (b), strengthening the fabric however by inserting layers of stainless steel wire which were woven into the asbestos fabric. By this means the life of the diaphragm was considerably increased. The frame (d) which holds the diaphragm, is made of special steel sections and is provided with narrow ribs to press the gasket tight against the electrode. This frame is lined with corrosion proof cement; since there are inside of the cell no metallic surfaces exposed excepting the electrodes, no secondary electrolysis can take place, a fact which is proven by the exceptionally high purity of the oxygen, 99.7%. The gases leave the cell separately through the pipes (e) and enter into the ducts (f) which, in the assembled battery, form on each side one continuous gas channel, one for Hydrogen and the other one for Oxygen, which can be seen on figure 6. (See page 36.) The arrangement of the gas discharge pipes outside of the cell has the advantage that any leakage can easily be detected and repaired.

The construction of the Bamag Electrolyzer is similar to that of the Pechkranz battery, the electrodes being assembled alternating with the diaphragms and clamped between

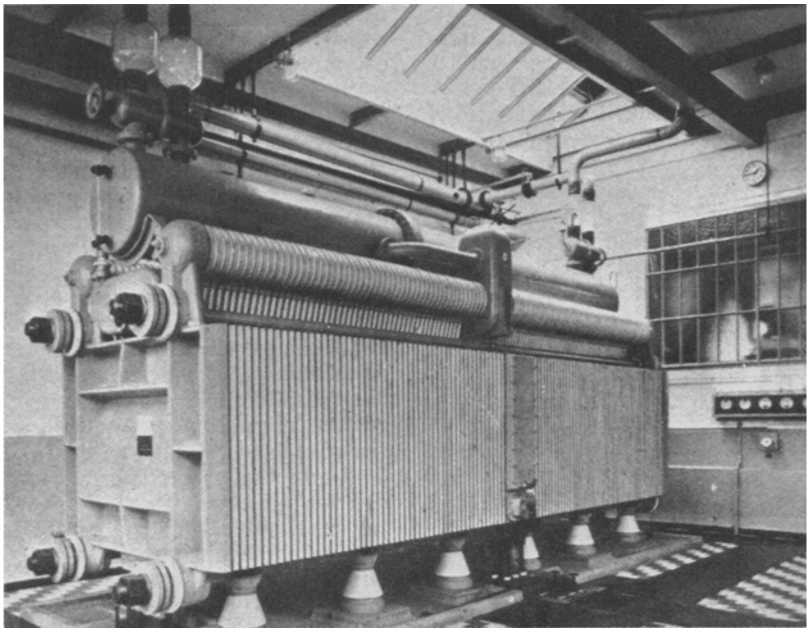


Fig. 6. The arrangement of the gas discharge pipes outside of the cell has the advantage that any leakage can easily be detected and repaired.

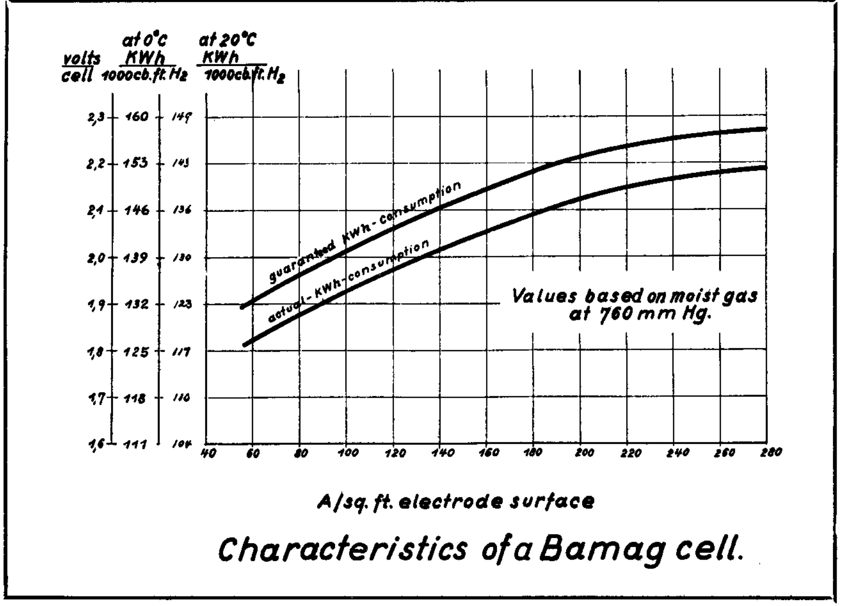
end plates of cast steel. In addition to the collecting ducts for both gases, there is on top of the battery a large partitioned drum for washing and cooling them. The two sections of this drum are communicating by means of a connecting tube with seal so that the same pressure prevails in both sections. Furthermore, they are provided with a safety outlet connected with the discharge valve so designed that, should a stoppage occur, the gas escapes through the safety pipe into the open air outside of the building. The battery rests on solid porcelain insulators.

The operation of the battery is as follows: the current enters at the plus terminal, flows consecutively through all cells and leaves at the minus terminal. The gases generated at the electrodes are separately conducted through the discharge pipes into the duct elements and from there to the top bell of the middle chamber. Then the gases enter into the drums where they are forced through a washing and cooling system so that all entrained liquor is retained. The gases leave the drum cooled down to a temperature about 15° F. higher than the temperature of the cooling water supply. The gases are discharged in a saturated state, corresponding with their temperature; the loss of electrolyte being thus as low as possible. Since the gases are relatively cool and dry, the insulation is so effective that tensions of up to 1400 volt for one circuit are possible.

The hot electrolyte entrained with the gases coming from the cells flows back through the middle chamber where it is cooled by means of water coils and returns from there to the bottom of the cells through a lateral pipe. Electrolysis implicates a consumption of water; therefore, distilled water must be continuously and automatically added to the contents of the system.

According to the number and size of the cells in a battery, the hourly output of a large electrolyzer amounts to from 3,500 to 17,000 cu. ft. of Hydrogen of 68° F. and 760 mm. mercury, batteries with small cells generate from 350 to

Fig. 7. Shows the ratio between power input and the KWH consumption per 1,000 cu. ft.



3,500 cu. ft. per hour. The load can be taken within wide limits, and one may practically calculate with a specific power consumption of from 116 to 140 KWH. per 1,000 cu. ft. of Hydrogen. The purity of the Hydrogen has always been 99.9%; with the latest installations a purity of 99.7% was reached for Oxygen. The largest battery built so far takes up 7,500 amperes at a voltage at the terminals of 350 volt, the power input amounting to about 2,600 KW. This is of high importance at the present time considering that some branches of the Chemical Industry consume power up to 100,000 KW. Electrolyzers of this type require only a fraction of the floor space occupied by unipolar batteries of the same capacity and under equal working conditions.

Another fact worth mentioning is that a large capacity plant of Bamag Electrolyzers can be arranged for automatic control. The addition of distilled water can be governed by a float valve and the quantity of cooling water, depending on the temperature of the electrolyte, can be regulated so that the attendance required for the plant consists of reading of the instruments and controlling of the liquor level indicators.

The economy of the Bamag Electrolyzer and its superiority over other systems has been proved by over 25 installations some of which have been in operation for 7 years. In no case has it been necessary to repair any of these cells. Due to the high purity of the gases, due to the novel design and construction of the diaphragm, these batteries are particularly suited for oil hardening plants, since a pure Hydrogen reduces the consumption of the catalyst and of the Hydrogen itself, thereby cutting down the operating expenses. In addition, the small amount of floor space required, the long life of the cells, their working safety in spite of little attendance, and finally their high efficiency decrease the general expenses for Hydrogen production.

That the oil industry has taken advantage of this new equipment may be seen from the following table:

Sales of Bamag Electrolyzers:

1930....................	2 units with a capacity of	370,000 cu. ft. of Hydrogen per day
1932....................	3 units with a capacity of	370,000 cu. ft. of Hydrogen per day
1933....................	3 units with a capacity of	425,000 cu. ft. of Hydrogen per day
1934....................	8 units with a capacity of	900,000 cu. ft. of Hydrogen per day
Total....................		2,065,000, or well above the total requirements of the American Hydrogenation Industry.

As to the cost of Hydrogen manufactured by electrolysis, the largest item is the charge for the current. Since the efficiency—consumption of KWH. per 1,000 cu. ft. of Hydrogen—is best at a low rate of production of the cells, it is sometimes advisable to select a type of larger size than really necessary. This is especially desirable when the cost of current is comparatively high. Figure No. 7 shows the ratio between power input and the KWH. consumption per 1,000 cu. ft.

Fig. 8. Shows the distribution of American dam-building projects.

By means of an electrolyzer the general cost of current can be reduced by absorbing the off-peak power load. This is not only feasible where the current is bought from the outside, but also desirable with large concerns who generate their own power (f. i. by the Diesel engine).

Our country is exceedingly "electricity-minded" as the following table[7] shows:

We are by far the largest producers of electric power; our per capita production gives us third place.

FIGURES FOR THE WORLD (1929):

Invested in electric power stations.................... 38 billion dollars
(Gold holdings of the world .... 22 billion dollars)
Production of electric power.................... 300 billion KWH.*

Distributed as follows:

U. S. A.	Germany	Canada	England	France	Italy	Japan	Switzerland
42.6%	10.5%	6.5%	5.6%	4.9%	4.3%	3.7%	2.0%
1040	490	2000	355	358	315	130	1500 KWH. per cap.

* (21 billion KWH., or 7% of total, used for chemical work.)

During the last decades, America has gone forward and has begun to build large dams in order to make better use of the enormous amounts of water Nature has given us. About 85 of these projects have been finished, among them the Boulder Dam, which was inspected by our President during the past month. Figure No. 8 shows the distribution[8] of these feats of American Engineering.

The majority of these constructions are in the Mississippi Valley and in the Middle West. These projects were built primarily for irrigation purposes and to counteract soil erosion. Undoubtedly, the surplus power will be made available to the Industry at a reasonable price and by this means the Chemical Industries and our own Hydrogenation Industry will derive their benefits.

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