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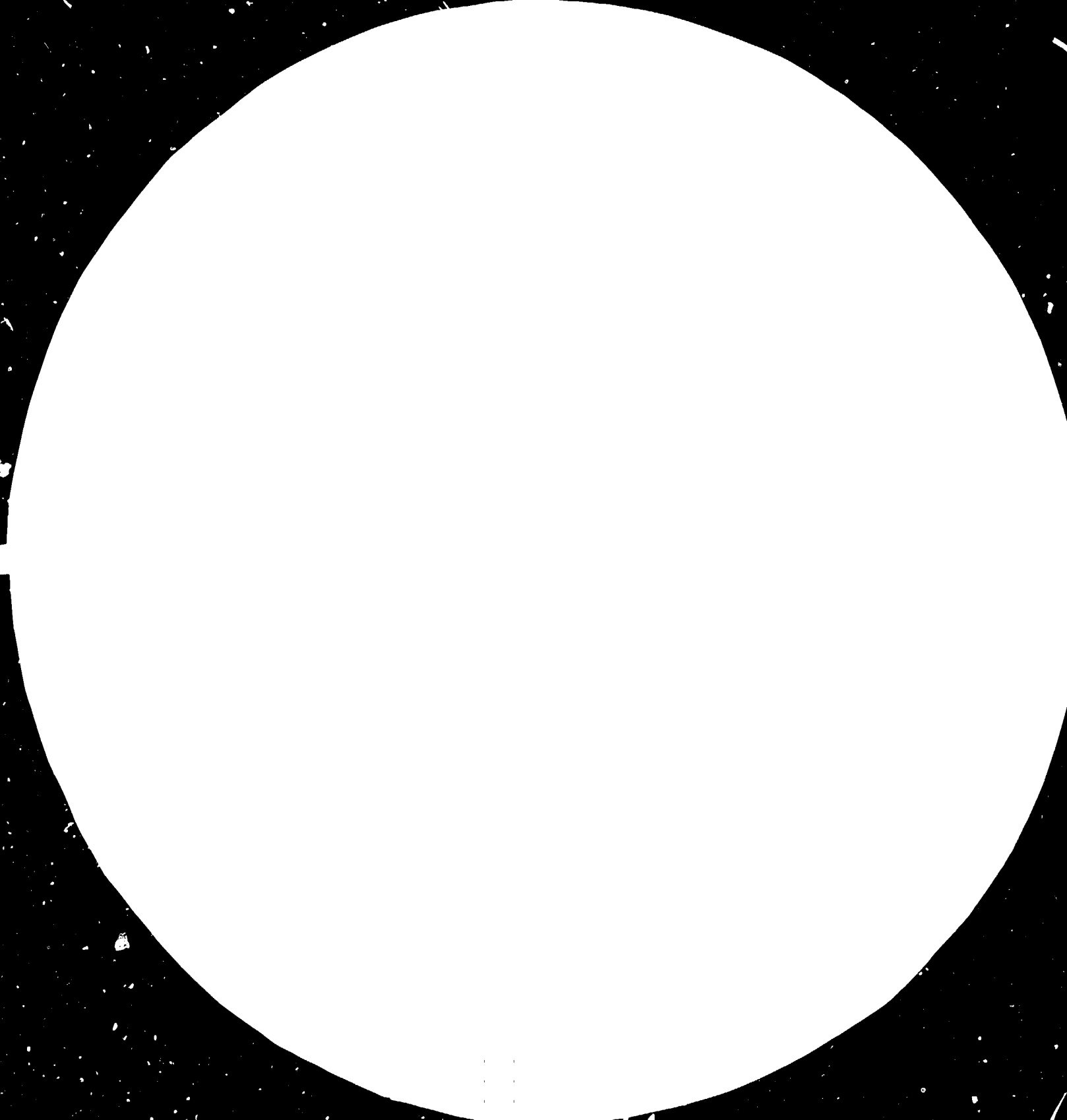
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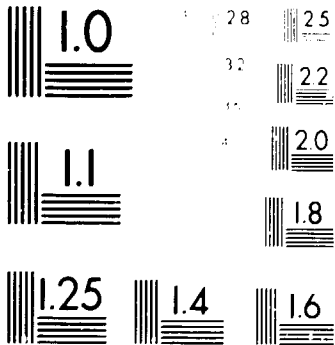
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MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS
 STANDARD REFERENCE MATERIAL 1010
 TABLE 1. MICROCOPY TEST CHART NO. 2

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ENERGY AND ENVIRONMENT
IN BAUXITE PROCESSING .

TEXT-BOOK
OF
VIDEO FILM .

MADE FOR UNIDO
BY INTERPRESS STUDIO
BUDAPEST

*D. Bulkai
K. Selyman*

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1983



ALUTERV-FKI

ENERGY AND ENVIRONMENT IN BAUXITE
PROCESSING

TEXT-BOOK

OF

VIDEO FILM

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INTRODUCTION

- 1.) Aluminium has been used only since the end of the last century when it was presented at the Paris world exhibition. Production of aluminium is a rather energy-intensive process, so aluminium goods are competitive only where the input energy is returned during the lifetime of the aluminium products, like in transport, or as regards the moving parts of engines. It is also used in food industry, due to its sterile surface as well as in electric power transmission, due to its good conductivity.

- 2.) Production of one ton of aluminium requires about 15 megawatt hour of energy, so it is an important precondition as to where we obtain this energy from. The blue field in our diagram indicates that more than 50 per cent of energy consumption by the world's aluminium industry is based on hydropower; the brown colour marks coal while orange stands for oil and gas,- the red for nuclear energy and the green for other resources...
This distribution differs in each continent. Where hydropower is not available, coal and nuclear energy are preferred to oil and gas.

- 3.) Nowadays, up-to-date smelters are used to process coarse, sandy alumina. This type of alumina does not dust and is suitable for dry gas scrubbing to avoid fluoride emission.

- 4.) Alumina is produced predominantly by- what is called- "the Bayer process" which consumes 2 to 3 tons of bauxite, 80 to 160 kgs of caustic soda, 8-24 gigajoules of heat energy and 250-400 kilowatt hours of electric power for the production of one ton of alumina.
Alumina production is concentrated in the vicinity of bauxite deposits while electrolysis plants are located

near cheap energy sources.

- 5.) On the map, the round shaped signs stand for bauxite deposits, the squares for oil and the triangles for coal deposits. Their size is proportional to their quantity.

Since bauxite deposits and energy resources are located in different parts of the world, either of the two must be transported to the other. The cheapest means of transport is shipping, wherever it is possible.

BAUXITE

- 6.) 90 per cent of the world's bauxite reserves are of laterite origin containing trihydrate aluminium-oxide called gibbsite and located in the tropical zones. The remaining ten per cent are of carstic origin containing monohydrate aluminium-oxide, called boehmite, or diaspor, located in subtropical and temperate zones.
- 7.) Bauxite deposits are being prospected by several boreholes. Bauxite deposits in Jamaica are covered only by a thin layer of soil, which is to be removed and stockpiled prior to open pit mining.
- 8.) Bauxite is excavated by high productivity machinery. They consume 1 or 2 per cent of the energy needed for aluminium production. The exploited areas have to be recultivated by the formerly removed cover-soil.
- 9.) In some countries, like in India, the ore must be shorted before shipping to the alumina plant.
- 10.) In other countries, like in Madagascar, bauxite is contaminated by clay minerals, for example kaolinite, which

can be removed by washing with water. Moisture must be dried out before shipping.

11.) Karst bauxites are found in sedimented forms in karstic holes. These bauxite deposits occur near the surface or at a depth of 100-200 meters.

While gibbsite can be digested at a temperature of 100 or 140 centigrade, boehmite is to be digested at about 240 centigrades and with caustic liquor of higher concentration. - However, the processing of local monohydrate bauxite- even of a lower quality- is economical if we take into consideration the high transport costs of laterite bauxite of low silica content and rising bauxite price.

12.) Open pit mining is predominant in the bauxite supply of the world. There is only a thin soil layer - often less than 1 meter over the surface of lateritic bauxite. It can easily be explored.

Only the overburden must be removed and high capacity excavators of low energy consumption can be applied for the exploration. However it is to be considered that infrastructure, transport facilities, like road, ropeline, railway, seaport are to be installed for the utilization. Therefore, the areas especially preferred for bauxite mining are those where high quality ore can be found and infrastructure is already developed. A further advantage is when the seacoast is near to the deposit and a proper port is available in the neighbourhood.

Long-distance railway or truck transport cannot be competitive from the point of view of energy saving.

In our picture, the pit produces about 500.000 tons of bauxite per year which can be achieved by the removal of five-six times more overburden. For local processing, this type of exploration can also be profitable. Due to the successful geological survey, the prospected bauxite reserves reached about 30 thousand billion tons recently. The amount of reserves increased much more rapidly than the bauxite consumption of the world. High energy prices increased costs, so the local processing can be recommended. Bauxite processing into alumina may help the industrialization of the developing countries possessing bauxite.

It must be emphasized that open pits must be returned to agriculture or forestry. The first step is the filling back of overburden. It is followed by the return of the soil.

In the case of lateritic bauxite, the rehabilitation consists of landscaping, drainage control, soil return, revegetation and monitoring.

13.) Rehabilitation.

14.) In some countries, deep mining is also used for bauxite exploration. Deep mines have much lower productivity, high exploration costs and require special safety measurements.

Machinery is to be adapted to the specialities of the given occurrence. Very often, only room and pillar work can be applied for the exploration, and ore losses reach up to 30 per cent. The importance of automated machinery, like the Cavo, you are seeing on this picture and Diesel engines is increasing.

The average energy consumption under such conditions

is 4-6 GJ/ton bauxite produced.

An up-to-date solution of ore transport in the mine is the conveyor belt system instead of mine truck.

- 15.) Modern massproduction causes higher contamination in the ore, through the mixture of silica, calcite and dolomite-rich overburden with the ore.

Sometimes, mining operations are to be performed under karstic water tables. In a given mine, 270 cubic meters of drinking quality water is pumped out every minute. The energy consumption of water pumping amounts to 80 per cent of total energy consumption.

This control room provides for the programming of water pumping and that of supplying public communities and industry.

- 16.) Bauxite is transported to the alumina plants, located within a distance of 40-50 kilometres, by trucks. For longer distances, railway transport is more economical. Bauxite, reaching the alumina plant, can be regarded as an energy carrier, containing all the energy which were used up for prospecting, mining and transport.

ALUMINA PRODUCTION

- 17.) More than 90 per cent of the alumina, produced in the world, is manufactured by Bayer process. This rate is not expected to be changed until the end of the century. We are dealing only with this process in our film. The efficiency of alumina refineries depends on the capacity of the plant. Nowadays, the minimum economical capacity is about 500.000 ton alumina per year, which means a one way (line) capacity. There are already 2 million ton per year capacity refineries as well. The

smaller and older plants may remain competitive only by continuous technical development, which aims particularly at energy and raw material saving.

Raw materials (bauxite, caustic soda, lime), primary and secondary fuel (oil, gas, steam and electricity) make up 60 to 70 per cent of factory costs.

- 18.) Bayer process is a chemical ore beneficiation technology. The diagram shows that the essence of the process lies in the alternative reaction of dissolving and precipitation of the alumina content present in the bauxite, which results in a closed circuit of the liquor.
- 19.) The first stage of the process is bauxite preparation, which consists of the reception of bauxite from truck, or railway wagon, optional homogenizing, crushing, grinding in caustic liquor, and pre-desilication.
- 20.) Although homogenization is a costly operation, it is required when the silica and other contamination content of the bauxite varies significantly.
- 21.) Grinding is one of the largest electric power consumers of the process, so it is recommended to stop in the energy peak-hour.
- 22.) The plant layout shows the modern designing principles of a Bayer plant. The main operations are located in blocks, arranged in such a way that the main material and energy streams are the shortest possible ones, thereby minimizing pumping and heat losses.

- 23.) After bauxite grinding, carried out in caustic liquor, the slurry will be preheated and predesilicated at about 100 centigrades in stirred tanks. The reactive silica content transforms into sodium-aluminium hydro-silicates. Slurry adjustment and preheating are the next operations before digestion.

- 24.) The slurry adjustment is based on chemical analysis of bauxite (in this case, by neutron activation analyser) and monitoring the chemical composition of test tank liquor (determined by conductivity measurement). The accuracy of adjustment determines the saturation of the blow-off slurry, thereby the amount of the spent liquor has to be heated up to digestion temperature.

- 25.) The adjusted slurry is fed into the digester line by special piston or membrane pumps. The piston pump you are seeing transfers the pressure to the slurry through clean liquor.

- 26.) Preheaters, placed before the digestion line are suitable for decreasing energy consumption. Actually, the autoclaves are heated indirectly and stirred mechanically.
The multiflash system serves for economical heating of the autoclaves.

- 27.) The volume of these autoclaves is 50 cubicmeters each. The actual energy consumption is about 4 GJ/ton. For the sake of decreasing investment costs significantly, even in colder climate zones, open air installation is preferred. Autoclaves are seen in the upper row, while below, the flash tanks are visible. Stirring is

necessary to avoid settling of bauxite slurry and accelerate diffusion.

- 28.) The tube digestion system is the latest development. This three-streams' construction enables the cleaning of the equipment under running, using caustic liquor alternatively in one of the three tubes, which will take part in the digestion also, after joining the streams before the holding tube. Due to the very good heat transfer, 30 per cent of the energy consumption of the autoclave series can be saved by tube digester. Investment costs are also 20 to 30 per cent lower and the equipment is fit to flexible operation.
- 29.) The application of energy saving measures and special equipment enables the reduction of the nowadays averagely used 15 gigajoules per ton alumina energy consumption of the Bayer process by 8 gigajoules.
- 30.) Digested slurry is expanded and separated by flat or conical bottommed thickeners.
- 31.) The mud phase is washed out in a 5 to 7 stages thickener series. For the sake of energy saving, these washer thickeners are linked in cascade by gravital flow.
- 32.) Clarifying and thickening is intensified by synthetic flocculants. This way, the organic level of the liquor is reduced compared to that of the starch-using. Caustic and alumina losses are also cut.
- 33.) In some plants, the red mud washing line consists of fewer stages and is closed by filtration. The latter

is a more expensive operation than thickening, however, the gains - by less liquor loss and more easily storable red mud- compensate for the extra costs.

- 34.) The clarified pregnant liquor is seeded by aluminium-hydroxide before the precipitation process.
- 35.) The temperature of pregnant liquor is lowered by heat exchanger. The precipitation tanks are stirred mechanically or by air lift.
Pressed air is prepared in a compressor station.
- 36.) The precipitation process needs sophisticated monitoring, since the grain size distribution and the productivity of the liquor is decisive in the plant's operation.
- 37.) The purity of the liquor (low carbonate and organics level) increases the liquor productivity, namely the Al_2O_3 transmission capacity of one cubic meter of caustic liquor which is an indication number of the plant's efficiency.
The hydroxide crystal structure which is built up during the precipitation process, determines the gas scrubbing capacity and dusting properties of alumina product which undergoes electrolysis.
- 38.) The crystallization process is also influenced by the quality of the recycling seed which can be one or three times more than that dissolved in liquor. Product hydrate is classified by grain size in hydroseparators and washed by clean condense water in two stages. The lowest adhesive moisture on the hydrate surface can be achieved by plain filters especially if synthetic

dewatering aids are added.

For evaporation of each per cent of moisture in hydrate, about 45 megajoules energy per ton is required.

- 39.) Aluminiumhydrate is used in several fields, like whitening, filling or absorbing materials, but 99 per cent is calcined for electrolysis.
- 40.) The first step of calcination is the release of adhesive and structural water. The second is the transformation of crystal morphology into a more compact form, namely alpha through gamma.
- 41.) Old rotary kiln calciners consume 5 gigajoules, equivalent to 130 kgs of fuel oil for 1 ton of alumina.
- 42.) About 20 per cent reduction can be achieved by retrofitting in fuel consumption.
- 43.) If old calciners are completed by extra accessories, like cyclons and fluid cooler, fuel consumption can be reduced to 100 kg/ton.
- 44.) Preheater cyclons represent another method of heat energy recuperation, while electrostatical particle condensers are needed for the protection of environment and reduction of dusting losses.
- 45.) Most of the calciners are heated by oil, emitting sulphuroxide and carbonmonoxide during burning. Natural gas heating is much cleaner - if available - both for the alumina products and to environment.

- 46.) "Pechiney" invented the replacement of burner and reached the same reduction in heat energy as by retro-fitting the rotary kiln with gas suspension calciner.
- 47.) The environment protection agency in Hungary allows 0,2 mgs per cubic meter of dust emission. The electrostatic filters can easily meet this limit.
- 48.) The latest development in calciner design resulted in the production of a stationary fluid type equipment which consumes only 3.4 gigajoules or 85 to 90 kgs of fuel oil per one ton of alumina.
- 49.) Liquor concentration is set by evaporation. The old Vogelbusch type equipment evaporates one ton of water by 0.4 ton of steam.
- 50.) An up-to-date evaporator , like the Kestner type, you are now seeing in the picture, uses 0.3 ton of low pressure steam for the evaporation of one ton of water. The scheme indicates the counter current liquor steam flow.
- 51.) The super concentrator unit provides for the removal of impurities in the liquor.
- 52.) The diagram shows the main waste energy flows and radiation losses of a Bayer plant which consumes 8,5 gigajoules for the production of one ton of alumina hydrate. The losses amount to 4 gigajoules.
- 53.) For the utilization of low temperature heat flows,

different types of heat exchangers are used. The main types are the plate-heat exchangers which are preferred for the cooling of clean liquors.

54.) Spiral or tube-in-tube heat exchangers are recommended for slurries.

55.) In the scheme of the Bayer process, all the points are indicated where heat exchangers can be used for energy re-cycling.

The price and operating costs of these equipment are rather high, however, nowadays investment costs return within a short period of operation, since energy costs are so high.

56.) There are more than one hundred centrifugal pumps of this size in an alumina plant. For the reduction of the energy consumption of the pumps, productivity must be controlled by frequency control, instead of throttling.

57.) With frequency control (marked with blue) energy consumption of the pump amounts to half of that consumed with the traditional throttling method (marked with red).

58.) Lime is an energy accumulator which contains five to six times less valuable energy than caustic soda. With soda causticization, one kilogram of sodium hydroxide can be gained by 2 or 3 kilograms of lime, so modern plants apply caustic soda regeneration.

In addition to that, lime or calcium-containing additives are used as catalyst at the digestion of diasporic and goethitic bauxite.

- 59.) The sodium-oxide, aluminium-oxide, water system concentration diagram indicates results of twenty years development in the Bayer technology, applied in a Hungarian refinery. The optimization of concentration ratios results in significant savings in energy consumption as well. The area closed by the lines of the circuit represents the efficiency of the technology. In a first approach, the smaller the closed area, the lower the specific energy consumption of the process.
- 60.) Instrumentation, process control and automation are determining factors in the process development and economy of energy. XRF and XRD methods provide the main analytical data for process control and avaluation of production efficiency. The most recently developed, combined XRF-XRD equipments are connected to the data collecting system of the whole process controlling computer.
- 61.) Computerized process control aims at obtaining not only the optimum of operations but the lowest production costs as well.
- 62.) To sum up: the minimum, the actual medium and the maximum energy consumption of the Bayer process, divided into the main process stages are shown. Sometimes the energy needed for the transport of raw materials may be equal to the entire energy demand of an up-to-date Bayer plant.
- 63.) In the most recently developed, high capacity plants, the total energy consumption can be lowered down to 8 GJ/ton of alumina.

RED MUD

- 64.) By average, for one ton of alumina, 1 ton (between 0.5 and 1.5 ton of residue) is produced which causes the gravest environmental problems of bauxite processing.
- 65.) Some refineries located near the seaside pump their residue directly or ship and discharge it to the sea. Even if red mud is discharged in deep water areas, the harmful effects of caustic soda cannot be avoided.
- 66.) The traditional disposing method is the red mud lake. These red mud ponds must be isolated perfectly, to avoid caustic infiltration into ground water, because they would contaminate drinking water wells and rivers. Large lakes cover agriculturally useful areas. Our picture shows a red mud lake which is formed among the dams of fly ash of the coal-fired power stations, that are cooperating with the refinery. The high calcium oxide content of the fly ash reacts with the sodium-aluminium-hydrosilicate content of the red mud, increasing the solidity and water-proof resistancy of the dam.
- 67.) Dissolved caustic soda and aluminium losses can be reduced by the re-circulation of the caustic water from mud like into the Bayer plant.
- 68.) By filling up a traditional red mud lake, it gets dried out and causes dust pollution. Therefore, it is necessary to plant useful vegetation into the surface of the mud lakes.
- 69.) Sometimes, natural valleys are closed for red mud disposal, like in Jamaica, as seen in this picture.

- 70.) Drainage of the mud pond provides for a perfect recovery of caustic and alumina losses, and accelerates the drying of the mud.
The methods mentioned here are applied for red mud slurry, originated from the last washer's underflow.
- 71.) With available filtration facilities, red mud is produced with a moisture content of about 40 per cent: thus it can be treated more advantageously.
Red mud can be considered as secondary raw material. Although a commercial process is not realized yet for its processing, nevertheless there are some research results which are potentially feasible.
- 72.) One of these possibilities is the complex processing. The first stage is the red mud causticization. Afterwards, red mud is smelted into self-desintegrating calcium-aluminate slag and pig iron. The slag is leached to recover its caustic soda and alumina content. Thereafter, the secondary grey mud is appropriate for cement production.
- 73.) Until such a process will be realized, filtered red mud can be disposed by the method now demonstrated.
The mud is made tixotropic and is pumped into the mud lake, so 4 to 6 times more mud can be placed to the same area.
- 74.) Dusting can be stopped by the plantation of different grasses, bushes and hawthornes without previous soil cover.
Normally, the ponds are returned to agriculture. In this case, soil must be spread into the surface and thereafter cultures, like rice and cabbage can be planted.

ENERGY SUPPLY

- 75.) Alumina production needs heat energy in the form of steam and electricity. It is very advantageous if the refinery cooperates with the power station when back pressure power generation can be installed.
- 76.) If there are no possibilities to cooperate with a power station, the alumina refinery needs its own boiler house for steam and electric power supply. Unfortunately, these minor power stations are operating with fuel oil. It might be more economical to build a coal-based power station of higher capacity and use it to provide the other industrial and public consumers, too.
- 77.) This oil boiler, you are now seeing, produces 70 bar steam for tube digester and supplies a back pressure power generator.
- 78.) The cost of electric power depends on the primary energy source. The data, you are now seeing, are related to the year 1990. As it is seen, fuel oil will be much more expensive than coal and even nuclear energy will also be slightly more expensive than coal.
- 79.) Traditional coal-based power stations are also contaminating the environment by sulphur-dioxide carbon-dioxide and dust.
- 80.) However, there are already fluid bed coal-fired power stations, with high energy efficiency and very low contaminant emission.
- 81.) Closed circuits of pure condensed water cause heat losses, which may be utilized in the future.

82.) The diagram indicates the total and per capita energy consumption of the industrialized and developing countries in 1981 and in 2000.

A fast increasing energy demand in developing countries - as basis of their industrialization - is expected.

It is very important to realize this aim by using the latest technology of energy generation systems.

83.) As it was seen in the film, the processing technology, the environmental protection, energy supply and conservation form a complex system.

The way to industrialization must not destroy nature and human environment, but has to be in harmony with it and in accord with Mankind's demand for a better life.

