LECTURE

TECHNOLOGIES AND EQUIPMENT FOR REMOVAL OF INDUSTRIAL RESIDUES AND WASTES, PARTICULARLY RESIDUES FROM CHEMICAL PROCESSES

Bernard Sinning

1 ORIGIN AND TYPES OF INDUSTRIAL RESIDUES

Many chemical production processes produce undesired by-products, off-grade products and intermediate products, which cannot be recycled or processed further and cannot be sold in their final state. There are only very few real recycling processes without such “waste products.” The proportion of these industrial wastes is particularly great if the final product constitutes only a small percentage of the raw material charged, and whenever the final product implies the use of many auxiliary substances.

With complicated processes (multi-stage operation) the quantity of the wastes decreases, but their variety increases.

There is a general public opinion that these wastes could be re-used to a great extent by recycling. This, however, is restricted to certain processes and can never be a general solution. Whatever in this representation is called “waste”, is a substance which has already passed the recycling stage.

The industrial wastes of this nature are the subject of this representation, but do not include municipal wastes. They can be categorized according to physical states: solid, pasty, liquid, gaseous; according to toxic properties: toxic and nontoxic, and according to solubility in water with respect to waste depositing.

In West Germany the Government regulations have created three categories of industrial waste:

Group I: waste which may be deposited, provided that certain precautions be taken to avoid contamination of soil, water and air.
   Examples: acid resins, tar residues and oily earth.

Group II: waste of organic origin which can be incinerated with or without pretreatment. The combustion gases must be cleaned from dust and harmful gases.
   Examples: used oil, waste oil, plastics, solvents.
   (This group is subject of this representation.)

Group III: waste of organic and inorganic nature which may be deposited only after chemical or physical pretreatment.
   Examples: acid, alkalis, caustic, water soluble salts of heavy metals, galvanizing sludges.

Accordingly, a complex process plant for industrial wastes must be divided into the sections:
   - pretreatment
   - combustion and
   - deposits

2 PURPOSE OF WASTE TREATMENT

The purpose is to transform the residues into harmless end products which will neither contaminate the ground nor the water and the air.

Composting is impossible since industrial wastes contain hardly any rotting substances.

A simple volume reduction by crushing, compression or dewatering often involves environmental pollution, therefore it is nearly always necessary to provide for incineration: ashes and slag have only 1/10th of the waste volume and are without environmental influence. In other words: they may be collected and deposited.
3 SELECTION OF COMBUSTION SYSTEMS

There are different criterions for the selection of the appropriate combustion system usually based on the following factors:

a) type, quantity and caloric value of the residues
b) storage and pretreatment
c) value of heat recovery (if any)
d) future types of wastes related to process changes

In the following we shall show you some typical waste compositions and the selected combustion equipment. This comprises five types of either kilns:

a) rotary kilns and burn-out chambers
b) fluid bed kiln
c) combustion chamber kiln
d) turbulator action kiln
e) grate kiln

The general rules for the application of these kiln types are:

a) Rotary kiln: the most versatile kiln for all kinds of waste in solid, pasty or liquid condition. Very flexible by distribution of the liquid waste feed between rotary kiln head and secondary combustion chamber.

b) Fluidized bed kiln: for pasty and liquid wastes like sludges and effluents from refineries, petrochemical plants and water purification plants; flexible for fluctuating throughput rates and wastes of varying composition. Wastes with low caloric value need a support firing.

c) Combustion chamber with special nozzles: for effluents with low caloric value and stinking matters, to be used where the expensive fluid-bed kiln is not necessary.

d) Turbulator: a high-temperature combustion chamber with turbulent gas flow for liquid wastes with high caloric value. Due to special refractory lining it can stand great thermal loads.

Suitable for pyrolysis and breaking-up of metal chlorides. Due to high gas velocities solids and dust are carried over. Therefore the off-gas cleaning is very important.

e) Grate: types utilized in incinerators with longitudinal overthrust grates and rotating basket grates, mostly in combination with steam boilers systems.

4 EXAMPLES OF TYPICAL INDUSTRIAL WASTE COMPOSITIONS

1: Wastes 3, 4 and 5 seem to require a fluid-bed kiln. But the bleaching earth inclines to sinter and cake which would spoil the sand filling of the kiln. In addition, the general waste ranging from bricks to canteen refuse should be burnt in the same kiln. The waste came from three different sources in containers in varying time cycles. Furthermore, liquid wastes were to be pumped to the kiln and to be burnt. If we sum up these requirements, the result is this: five different residues from three different plants, containing 10 to 50 percent ashes, 0 to 60 percent water, with caloric values of 600 to 8,000 kcal/kg are to be burnt-out according to government regulations.

The batch-wise feed to the kiln and the varying properties of the wastes are “ironed out” in a homogenizing drum which resembles a rotary kiln. This drum has a capacity of 20 hours throughput and can be operated with inert-gas (gas without oxygen). We selected the rotary kiln for this application, because it has proved to be the most versatile and flexible one of the kilns available.

2: represents residues which are supposed to be burnt in fluid-bed kilns. It is the effluent from a petrochemical plant.

3: represents biological sludge, liquid and pasty residues from a refinery containing not too much salt. It is advisable to mix these components in order to homogenize their varying properties. If we sum up, we see clearly the application range of the fluid-bed kiln: wastes with homogeneous properties, pasty and liquid (like sludges and effluents) with throughput rates varying to a large extent. The fluid-bed kiln can tolerate these fluctuations of the throughput rate!

4: typical wastes which are best suited for combustion on grates, which may be either longitudinal or rotating are listed here. They are not suitable for wastes which tend to melt at low temperatures. They are also not applicable for trickling residues which might fall through the interstices of the grates.

5 LAYOUT AND DESIGN OF INCINERATION PLANTS

Fig. 7: shows as a block diagram in the upper branch the alternative with heat recovery, in the lower branch the alternative without heat recovery.

The latter solution will be preferred, whenever an outlet for the heat cannot be found and/or corrosion problems would turn up with the heat recovery equipment. In normal cases, the heat recovery equipment should be used to take advantage of the heat produced from waste.
<table>
<thead>
<tr>
<th>Type of waste</th>
<th>Conc.</th>
<th>Condition</th>
<th>Water</th>
<th>Ash</th>
<th>C.V.</th>
<th>Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td></td>
<td>%</td>
<td>%</td>
<td>kcal/kg</td>
<td></td>
</tr>
<tr>
<td>General trash</td>
<td>11</td>
<td>solid</td>
<td>10</td>
<td>20</td>
<td>1.500</td>
<td>container</td>
</tr>
<tr>
<td>Bleaching earth</td>
<td>42</td>
<td>crummy</td>
<td>--</td>
<td>50</td>
<td>5.000</td>
<td></td>
</tr>
<tr>
<td>Filter cake</td>
<td>30</td>
<td>&quot;</td>
<td>60</td>
<td>5</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>Oily wastes</td>
<td>8</td>
<td>pasty</td>
<td>15</td>
<td>5</td>
<td>8.000</td>
<td>bags</td>
</tr>
<tr>
<td>Slop oil</td>
<td>9</td>
<td>liquid</td>
<td>10</td>
<td>--</td>
<td>8.000</td>
<td>pumped</td>
</tr>
</tbody>
</table>

Composition of Residues of a Petro Chemical Plant

FIG. 1
<table>
<thead>
<tr>
<th>Type of Waste</th>
<th>Water %</th>
<th>Ash %</th>
<th>C.V. kcal/kg</th>
<th>Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refinery effluent</td>
<td>90-96</td>
<td>1,3</td>
<td>500-1,500</td>
<td>pumped</td>
</tr>
<tr>
<td>containing:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 % Metalhydroxides</td>
<td>--</td>
<td>80</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>70 % Oily residues</td>
<td>--</td>
<td>5-10</td>
<td>6.000-10.000</td>
<td>--</td>
</tr>
</tbody>
</table>

Composition of the Effluent
of a Petro-Chemical Plant

FIG. 2
<table>
<thead>
<tr>
<th>Type of Waste</th>
<th>Conc. %</th>
<th>Water %</th>
<th>C.V. kcal/kg</th>
<th>feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasty:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Effluent sludge</td>
<td>85</td>
<td>93</td>
<td>--</td>
<td>pumped</td>
</tr>
<tr>
<td>Liquid:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Liquid</td>
<td>8</td>
<td>--</td>
<td>5.800</td>
<td>pumped</td>
</tr>
<tr>
<td>3 Semi-liquid:</td>
<td>7</td>
<td>5</td>
<td>7.500</td>
<td>pumped, barrels</td>
</tr>
<tr>
<td></td>
<td>Esters, Gasolines, Alcohol, Methanol, Xylol, tar, activated carbon</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Composition of Residues of a Chemical Plant

FIG. 3
<table>
<thead>
<tr>
<th>Type of Waste</th>
<th>Conc.</th>
<th>Water</th>
<th>Ash</th>
<th>feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Chlorinated HC from various polymers and monomers</td>
<td>100</td>
<td>--</td>
<td>traces</td>
<td>pumped</td>
</tr>
<tr>
<td>2 Metaloxides</td>
<td>traces</td>
<td>--</td>
<td>traces</td>
<td>pumped</td>
</tr>
</tbody>
</table>

Composition of Residues with high C.V. from a Chemical Plant

<table>
<thead>
<tr>
<th>Type of Waste</th>
<th>Conc.</th>
<th>feed</th>
<th>final product</th>
</tr>
</thead>
<tbody>
<tr>
<td>FeCl₂-solution:</td>
<td></td>
<td>pumped</td>
<td>125 g/l-Fe₂O₃ / FeCl₂-solution</td>
</tr>
<tr>
<td>water</td>
<td>80</td>
<td></td>
<td>40 g/l-HCl* / FeCl₂-solution</td>
</tr>
<tr>
<td>FeCl</td>
<td>20</td>
<td></td>
<td>*adiabatic: 20.4%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>*isothermal: 32%</td>
</tr>
</tbody>
</table>

Composition of Residues of a Pickling Bath

After Pyrolysis

FIG. 4
BASIC UNIT OPERATIONS
OF AN INCINERATION PLANT FOR INDUSTRIAL WASTES

COMBUSTION AIR

WASTES and TRASH
solid, pasty, liquid

PREPARATION
Crushing, storage, blending, feeding

INCINERATION
Drying, smoldering, incineration, post-combustion

RESIDUES:
SLAG and ASH

COOLING MEDIUM
Water, Steam, Air

OFF GAS COOLING
direct, without heat recovery
indirect, with heat recovery

CLEAN OFF GAS

RESIDUES:
Ash and sludge

FIG. 6

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An integrated plant for industrial waste incineration is usually divided into four sections:

- Storage of the wastes
- Combustion
- Heat recovery of removal
- Off-gas cleaning

Slide 7 shows you the process flow-sheet on which you can see these sections.

A description of plant and process will follow the lines of this flow-sheet.

It has proved to be economical to build these plants for a minimum capacity of 10 to 12.5 gcal/h. If this is considered a module, bigger plants may be built with the same elements in sizes of 25, 37 and 50 gcal/h.

**Liquid wastes:** The store is a tank yard with normally five storage tanks having a capacity of 10 to 30 days depending on the waste quantities supplied. There are three tanks for:

- Water insoluble matters (settling tank)
- Water soluble matters
- Wastes requiring special treatment

And 1 tank to homogenize the content of these 3 tanks. The 5th tank is to store the fuel oil for ignition and auxiliary burners. All tanks except the 5th one are equipped with heating coils and electric heating in case of steam failure. They are made of stainless steel and have agitators.

**8. COMBUSTION**

The governing value for determining the size of kiln and the following flue gas cleaning equipment is the thermal load: tons per hour \(\times\) calorific value. The liberated heat determines the flue gas volume rather than the throughput by weight. And the flue gas volume is the determining factor for all equipment sizes.

To adapt the rotary kiln to various wastes, its speed is variable in a wide range, thus controlling the residence time of the wastes.

The combustion air consists of both primary air which distributes the liquid wastes in the burner (atomizing air) and secondary air which is blown by a fan via the front head into the rotary kiln.

For start-up and as support firing to compensate for wastes with low calorific value a fuel oil support burner is installed in the front head of the kiln which is actuated by the temperature controller at the kiln discharge side.

**AFTER-BURNER CHAMBER**

The combustion gases leave the rotary kiln at the discharge side and enter the after-burner chamber for total combustion. According to German regulations, the minimum residence time of the gases in the chamber is 0.3 s. at 900°C. The chamber is designed to allow for one second with gas velocities not greater than 5 m/s.

For incineration of all kinds of fuel oils and liquid wastes rotary cup burners with atomizing jets are installed in the lower part of the combustion chamber; the burners are supplied by 4 ring mains.

**9. STEAM GENERATION, HEAT RECOVERY OR HEAT REMOVAL**

The flue gases at a temperature of approx. 1000°C (1830°F) transfer their heat to a steam boiler or hot oil furnace, whatever is preferred by existing energy consumers.

We focus here on the steam boiler.

The gases leave the boiler at a temperature of 270°C (518°F) (with clean walls) and are given to the electrostatic precipitator.

The boiler consists of a gas-tight welded cage of pipes with bulkhead walls built-in which form several passes for the flue-gases. The emphasis is placed on radiation, there is little convection area.

The walls are welded of alternate pipe — bar — pipe configuration as shown. — Slide 8

The distance of the pipe walls is large enough to allow for a man to work in the passes for repair purpose. Access to the passes is presented by covers without piping in the ceiling of the boiler. For each pass side openings are provided which permit cleaning from the outside.

Forced circulation is applied to the interior walls only. The exterior walls have natural circulation.

The ash hoppers have steep inclined walls to avoid plugging and sticking in the discharge chutes. These chutes are combined and given into a submerged slag remover.

The boiler is suspended in a steel structure to allow for thermal expansion towards the ground. Platforms are provided.

The steam can be totally condensed in air condensers. This occurs whenever the steam consumer has no demand for steam, since the boiler feed water must be recovered in any case.

A favorable alternative for steam generation is the recuperation of the combustion energy as hot...
air: This air may either be utilized as preheated secondary air or as drying medium for spray-dryers or for thermal conditioning of effluent sludge.

In these cases the heat exchanger (recuperator) is made from cast steel with up to 28 percent chromium for the higher temperatures. The normal design is a double shell system with concurrent flow of gases and heat transfer by radiation (1200 to 600°C). The following stage, cooling down to 300°C, will be by convection in tube bundles with counter-current flow of gases.

The heat removal becomes stringent whenever a consumer of steam, hot oil or hot air cannot be found. Apart from diluting the flue gases with fresh air—which is not permitted in Germany—the heat can be only removed by condensation of steam (which implies a boiler) or by injection of water which is vaporized and increases the flue gas volume considerably. For an effective heat exchange, a large area of water droplets is required and a favourable shape of gas and liquid currents.

10 FLUE GAS CLEANING

In modern waste incineration plants, great emphasis is placed on cleaning the flue gases so thoroughly that they can be emitted into the atmosphere with the following maximum loads of harmful ingredients:

- German Regulations at the present state of the art “TA Luft” — calls for

  - Cl: 100 mg/Nm³
  - SO₂: 100 to 400 mg/Nm³
  - F: 5 mg/Nm³
  - CO: 1 mg/Nm³
  - Organic: 50 mg/Nm³
  - Dust: 100 mg/Nm³

All these values are related to an CO₂ content of 12 percent (55 percent Excess-Air) in the off-gas. This condition is set to prevent dilution by fresh air which is undesirable.

For dedusting mechanical, electrical and absorptions methods are available separately or in combination such as: Mechanical — Electrostatic Precipitators — Scrubbers.

11 REMOVAL OF SLAG AND DUST

A separate wet deslagger with discharging apron conveyor is arranged behind the kiln.

A submerged scraper is provided under the boiler for fly ash discharge.

The fly ash discharged from the electrostatic precipitator is handled by rotary valves and tubular screw conveyors to the submerged scraper below the boiler.

Slags and ashes are taken by belt conveyors to movable containers. Iron components are removed by a magnet separator and discharged into separated containers.

12 KILN FEEDING AND EQUIPMENT

In the field of feeding various proven methods are available which are not too complex to go into any lengthy detailed illustration or discussion.

13 ROTARY KILNS

The rotary kiln is the most versatile kiln and most effective in the control of slag formations.

Certain groups of residues require the lowest possible combustion temperature — lower than sintering temperature — whereas others may require high combustion temperatures, when the slag starts to melt. In the rotary type of kiln the liquefied slag sticks to the refractory, forming an “annulus fur.” The slag moves via this fur in its liquid state to the slag remover.

This process calls for higher combustion temperatures and consumes more energy which may mean greater consumption of support fuel. It also yields, however, an additional protection of the refractory lining.

The thermal duty of a rotary kiln is usually 1 to 1,5 gcal/h per m² kiln area (cross section). The nature of compounds and the resultant gas volume determines the residence time in the kiln: double-bond hydrocarbons, tars and polymers need more residence time for combustion than those hydrocarbons which are easily cracked.

Substances with a great deal of inorganic matter will increase the solids concentration in the flue gas. Examples are bleaching earth and pigments. In this case the gas velocity in the kiln should not be greater than 3 to 4 m/s (10 to 13 ft/sec) to avoid too much carry-over by the combustion gases.

The after-burner chamber is designed for a thermal load of 2 to 2,5 gcal/h per m² area (cross section) along with a gas velocity of not greater than 3 to 4 m/s.
Abb. 10. Schema für auswechselbaren Multiklon.

FIG. 9
HCl-Konzentration im Waschwasser (Gew.-%)

HCl-Gleichgewichtskurven für niedere Konzentration.

FIG. 11
Abb. 6
Vergleich einer einstufigen SO₂-Wäsche
mit
a) Wasser im Durchlauf
b) Na OH, pH-Wert 11—12, 20° C
Faßentleerung und Aufschmelzvorrichtung

normalflüssige Abfälle

flüssige Abfälle mit hohem Stockpunkt

zum Vorratsbehälter

FIG. 12
pastöse Stoffe
Kastenbeschicker
Schleuse
Kippvorrichtung
Drehofenstirnwand
Faßaufgabe

FIG. 13
Horizontale Einstoßvorrichtung für Feststoffe in der Drehrohrenstirnwand

1 Stößel
2 Aufgabeschüssel
3 Andruck- und Verschluß-Deckel
4 Schwenkvorrichtung für 3
5 Verbrennungsluftinblasung
6 Brenner für flüssige Abfälle

FIG. 14
Brenner für flüssige Abfälle mit Feststoffanteilen

Brennstoffdüse

Zerstäuberdüse

Zentriertell mit Drallkanälen

Drallkanäle

Brennergehäuse

Zerstäuber-Hilfsmedium

Brennstoff

FIG. 15
Zweistoffbrenner für flüssige Abfälle und Zusatzbrennstoff

Verbrennungsluft

Dampf

Flüssige Abfälle

SLIDE 16
Ölbedarf für Stützfeuer
bei Abfallverbrennung bei 1000°C und bei 900°C
(Öl: Hu = 9600 kcal/kg)

FIG. 17
FIG. 17a
MATERIALEINTRAG IN OFEN

FIG. 18
The height of this chamber must allow for a residence time of 1 s for the off-gas, measured from the last burners in vertical direction. This will ensure a complete oxidation of the gases, since a minimum temperature of 900°C (or 1100°C depending on the chemical composition) is maintained by temperature control.

Slide 17 shows the effect of air ratio vs. the calorific value on the combustion process.

With an off-gas temperature in the after-burner chamber of 900°C and a calorific value of 3500 kcal/kg, the combustion needs so much energy for the off-gases and radiation losses that a support firing of 35 kg fuel-oil per ton of residue is required to meet the heat balance.

7 DESCRIPTION OF THE CENTRAL PLANT FOR INDUSTRIAL WASTE DISPOSAL FOR BAVARIA

The idea of this great installation — at present the largest plant of this kind in Europe — is to process all industrial wastes collected by law for this area.

All industrial firms down to the smallest ship are obliged to deliver their wastes to a company which was established for this purpose and which is obliged to accept all the residues and dispose of them by incineration. The shareholders of this company are both industry and government (municipal and state). All waste processing becomes mandatory by this procedure and no one has the excuse not to know where to deliver his wastes. The central plant has a laboratory to check all incoming wastes and to distribute them to the proper storage and treatment areas.

The annual capacity is approximately 100,000 t/year of solid, pasty and liquid residues with a mean calorific value of 3,300 kcal/kg. The thermal capacity is 25 gcal/h. It is processed in two parallel rotary kilns having one common after-burner chamber (Slide 20). The plant is layed out to add a third kiln some time in the future.

Bunkers for the solids have a capacity of 900 m³. They are controlled by a crane operator from a stationary location.

For pasty residues 4 steam-heated bunkers of 100 m³ capacity each are provided.

The tank yard for liquid wastes has a total storage capacity of 200 m³. Beside it is located the barrel melting cabinet.

Each rotary kiln can handle either 5 t/h solids with a net calorific value of 2500 or 3,1 t/h pasty wastes with a net calorific value of 4000, or any combination which does not exceed 12,5 gcal/h.

The after-burner chamber handles the off-gases from
a) 2 rotary kilns without burning additional liquids or
b) 1 rotary kiln and in addition 2,4 t/h liquid wastes with a net calorific value of 5200.
These liquids are burnt in the side walls.

The vertical gas velocity is 3.5 m/s in the after-burner chamber at a thermal load of 25 gcal/h.

The off-gas at a rate of 66,000 Nm³/h leaves the after-burner chamber at a temperature of 1000°C.

Heat is recovered in a steam boiler. The gases leave the boiler at 270°C. Steam is generated at 25 atm and superheated to 250°C at a rate of 34 t/h.

A steam turbine generates electric power at the rate of 1320 kw/h consuming 22 t/h steam. The remainder is condensed in an air condenser. This electric energy is sufficient to supply the entire plant’s demand requirements. The steam from the turbine — 3 ata — is utilized for heating the building and for process heat in the CP-plant.

The off-gas is cleaned with high efficiency by an electrostatic precipitator followed by a two-stage radial flow scrubber. Dust, HCl, HF are nearly completely removed, SO₂ removal is in the order of 70 percent. The scrubbing liquid is circulated at a rate of 150 m³/h. Since 2 m³/h are discharged to keep the concentration at a constant value and 10 m³/h are vaporized in the two scrubber stages, some 12 m³/h fresh water is supplied to the system. The discharged water carries sludge from the neutralizing agents and is further processed in the CP-plant. The saturated off-gases are reheated before leaving the stack to avoid condensation of the gas steam. This is accomplished in a heat exchanger and by addition of preheated air before the gases are exited to the stack.

The gases leaving the stack are almost completely free from toxic ingredients. They consist of nitrogen, oxygen, CO₂ and H₂O as they normally exist in the atmosphere.

Slag and ashes are deposited at a selected sanitary land fill and constitute approximately 1/10th of the original volume of the materials charged.

CONCLUSIONS

The purpose of waste removal is to provide for hygienic and harmless treatment of wastes with all their components that involve environmental pollu-
tion and with a view to facilitate disposing of the remains in an environmentally acceptable manner.

Each process of waste treatment will be subject to different emissions that cause air and water pollution. It is therefore necessary to develop a process that will result in producing a minimum of environmental molestation, and where the wastes are always environmentally controlled. In nature, organic substances are decomposed by oxidation to carbonic acid and water, i.e. the same end products as with incineration. From these products, the plant is building up carbohydrates, and thus a biological cycle is developed.

Mass production results in an increasing amount of metabolic products, i.e. waste gases, waste water and refuse. Decomposition of these matters cannot be left to be discharged to the environment without control. Neither can the problem be solved by shifting these discharges to existing sewage systems. Our rivers and oceans must be kept clean as a basis for future life. Rivers that by the irresponsible draining of wastes and waste water have been virtually turned into sewers, must be revived to new life, i.e. they must be made clean again and thereby offer clean natural environmental conditions for marine life.

Existing regulations requiring controlled on-site removal have now alerted those people, that formerly considered waste incineration unnecessary, recognize the importance of controlling such discharges. Refuse disposal represents a major problem. Properly controlled refuse incineration is therefore indispensable when the time for depositing is short and when the self-cleaning power of nature has been abused.
LIST OF FIGURES

no.
1 composition of residues of a typical petrochemical plant
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3 biological sludge and refinery residues (WS)
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17a gas volume, calorific value and temperature (diagram)
18 fluid-bed kiln, -section
19 fluid bed kiln plant
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20a IVA plot plan: storage and incineration
21 IVA longitudinal section

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