CONVERSION TO COAL IN DU PONT

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Coal accounts for a much larger share of the fossil fuel burned in Du Pont plants to produce steam now than at the time of the oil embargo in 1973. Most of our increased use of coal has been made possible by rehabilitating the support systems of existing boilers inherently capable of burning coal and installing pollution control equipment enabling them to meet new emission regulations. The remaining increase results from the construction of new coal-fired powerhouses in five plants.

Although we are evaluating coal gasification, fluidized bed combustion, burining of coal-water mixtures, etc., none of our increased use of coal thus far employ these methods. Our progress has resulted from the nitty gritty application of pulverized coal and spreader stokers equipped with electrostatic precipitators, baghouses, or two-stage mechanical dust collectors. The newest plants employ staged combustion of pulverized coal for control of NO_x and microprocessor-based combustion controls and burner management systems to maximize boiler efficiency and hold the number of operating personnel to a minimum.

I will describe a few of the retrofit projects, as these may help others in their coal conversion plants, then describe features of our new powerhouses, and conclude with a brief report on our studies for the future application of coal.

Du Pont's fuel distribution on a percentsge basis for the generation of steam since 1965 is shown in figure 1. In 1967 coal met 64% of our needs but decreased from that point to 22% by 1973. The reason for the declining use of coal was twofold, environmental and economic.

Plants found it increasingly difficult to meet emission regulations while burning coal without significant capital investment. Meanwhile gas and oil were readily available and lower in overall cost, particularly gas at its artificially low, controlled price. At the time of the embargo we were burning less coal than at anytime since World War II on and annual basis. Even at this low point, 11 of our coal-capable plants were utilizing coal as their primary energy source. However, in nearly all of the 11, coal was being supplemented with large amounts of gas and oil.

Since that time all coal-capable plants have been equipped with the necessary particulate removal equipment to meet emission regulations, and they currently burn only minimum amounts of oil or natural gas. In addition since that time, two new plants have been completed that use coal as a primary energy source. Our coal-burning plants have increased to 15 since 1973.

These changes have caused the slow but steady increase in the use of coal showmin figure 1, so that by the end of 1981 it supplied 45% of our boiler fuel needs. One more pwerhouse has been returned to coal in 1982. An additional new powerhouse is starting up now, and another will be on line during the first half of next year. If these powerhouses had been on line in 1981, our coal portion would have exceeded 50%.

In all cases we have chosen to meet sulfur dioxide emission limits by burning compliance coal in preference to installing scrubbers.

In Du Pont's coal conversion effort has been undertaken and completed since 1973. Forty-four boilers which had coal burning capability were equipped with electrostatic precipitators, baghouses, or two-stage mechanical dust collectors, plus, in some cases, new pulverizers, fans, hoppers, and coal and ash handling systems.

Ten boilers were adequate for 100% coal burning with no modifications. Seven new boilers with all their supporting facilities have been erected in four new powerhouses.

The boilers average 160M lb/hr in size, ranging from 40M to 550M. Their average age is 34 years, and several are over 45.

The effort has taken place at 18 plants in 10 states, each with its own environmental control regulations.

The new powerhouses and retrofitting of the existing boilers have required a total investment exceeding one quarter of a billion dollars.

The coal burned in these boilers causes Du Pont to be one of the nation's largest industrial consumers of coal for the generation of steam.

Rehabilitation of Coal-Capable Boilers

Forty-four boilers which were installed 20 to 45 years ago to burn coal had gradually shifted away either partially or completely from coal for economic and environmental reasons. The task of returning these boilers to 100% coal involved rehabilitating coal and ash storage and handling systems and equipping the boilers with precipitators, baghouses, or two stage mechanical dust collectors to control opacity and particular emissions. I'll cite some examples of the latter equipment and our operating experience with it in hopes that these examples will help others embarking on the same task.

Five boilers at this plant were installed in 1934 through 1937 to burn pulverized coal and discharge flue gas and fly-ash through mechanical dust collectors to a common breeching and stack.

After evaluating the possible installation of individual baghouses and precipitators for each boiler, the economics dictated installation of four precipitators, with four fields each, common to the five boilers, such that each precipitator can be isolated for maintenance. The stack emission regulations to be met were an opacity less than 20% and particulates less than .15 lb/MM BTU. Figure two is a plan view showing how diversion valves and breeching were installed to force the flue gas from the five boilers through the precipitators enroute to the stack.

Figure three is an elevation view showing isolation valves for each precipitator.

The isometric view in figure four shows rather clearly how the boiler flue gas leaves the common breeching and passes through the common precipitators enroute to the stack.

The boiler ID fans were replaced with larger fans to accomodate the extra pressure drop caused by flue gas flowing through the precipitator and its breechings. The precipitators in this case are on the positive pressure side of the ID fans, an arrangement which resulted in the lowest investment. The trade-off is that any gasket or seal leak causes flue gas and possible fly-ash to leak outside and create a housekeeping problem.

The isolation valves, which are closed to permit inspection and maintenance of an individual precipitator while other precipitators are in service, are double guillotine valves with an air purge between the guillotines.

At the plant in figure five, three boilers had been installed from 1946 through 1965 to burn pulverized coal discharging flue gas and fly-ash through mechanical dust collectors to a common breeching and stack.

Economics dictated installation of a large baghouse common to all boilers in which individual modules can be isolated. The effluent from individual boilers can bypass the baghouse if an emergency arises or if a boiler is required to burn oil. (see figure six)

Booster fans were installed and are powered by variable frequency drives to maintain negative 2" H_2O pressure at the baghouse inlet. The booster fans of necessity are sized for maximum boiler output combined with maximum pressure drop across the baghouse. Since these conditions rarely if ever occur, the fans run well below rating, and variable frequency drives are justified on the basis of energy saved by running the fans at low speed compared with running the fans throttled at rated speed.

Individual boiler draft controls are unaffected by variations within the baghouse because induced draft fans always discharge to a constant pressure.

This outside view in figure seven shows the common baghouse and breeching to the stack. The picture was taken before the baghouse was placed in service. Notice the plume at the stack.

The picture in figure eight was taken after the baghouse was placed in service, and you can see that the stack effluent is absolutely clear. Opacity monitors typically show an opacity of 2%.

Oil has been burned on occasion along with coal in ratios up to 50% in boilers discharging into this baghouse with no deleterious effect on baghouse performance.

The plant in figure nine contains six spreader stoker fired boilers discharging in pairs to three stacks. The emission regulation to be met is less than 10% opacity and a quantity of particulate that would correspond to .09 lb/MM BTU with all boilers operating at full load.

The boilers were treated in pairs in that a pair of boilers share one stack. One boiler of the pair has been equipped with a baghouse and the other boiler with a two-stage mechanical dust collector. Each pair of boilers, when operating together, meet the opacity and particulate regulations with some margin to spare. If the boiler with the mechanical dust collectors is required to run while its partner with the baghouse is out of service, the particulate limit is not exceeded because the dual mechanical collector passes less than .20 lb/MM BTU and the total particulate discharging from the three stacks is less than .09 lb.MM BTU of rated capacity of all the boilers connected to the three stacks. Under this mode the boiler operators must take care not to exceed the 10% opacity limit.

Successful operation at this plant has led us to adopt the same design at two other plants where spreader stoker fired boilers share common stacks. The saving in investment and operating costs compared with an installation having a baghouse on every boiler is considerable.

Figure ten shows a baghouse serving a spreader stoker fired boiler at yet another plant. Note the protected aisleway between the modules. Access doors to the modules open to the aisle and are thereby protected from direct rain and snow. When a module is removed from service for maintenance or because the load is low, the inlet and outlet module isolation valves are closed and the access door is opened. Since the baghouse is under negative pressure, the inevitable leakage through the inlet and outlet valves causes outside air to flow into the module through the access door. We have found that this method of isolating a module keeps the ash on the bags within that module reasonably dry.

We've reached some conclusions as a result of operating baghouses and precipitators over the recent years.

- Baghouse performance has been consistently excellent. Bag life can exceed four years unless a corrosive condition is allowed to exist.
- Electrostatic presipitator performance depends upon the resistivity of the ash-fly. If a question exists on resistivity of ash from coals to be burned throughout the life of the boiler, the precipitator should be installed before the last heat trap (a hot precipitator installation).
- The temperature of flue gases entering a baghouse should be at

least 325°F and not over 500°F, and the leaving temperature should be at least 300°F or about 20°F above the acid dewpoint to avoid corrosion of the bags. The acceptable low end temperatures for a precipitator are slightly less than for a baghouse.

- A baghouse should always operate under a negative pressure so that outside air will infiltrate a module that has been removed from service.
- For stoker-fired boilers, a mechanical dust collector should be installed ahead of the baghouse so that it can trap burning cinders which would otherwise burn holes in the bags or cause a hopper fire. For pulverized coal fired installations, a dust collector is not needed ahead of the baghouse.

New Powerhouses

During the 1960's and 70's a number of factory assembled boilers designed to burn gas and/or oil only were installed in our plants. These boilers have no provisions for ash hoppers along the gas passes nor provision for ash removal from the furnace. Conversion to coal firing in such a boiler is virtually impossible.

Figure eleven shows a side elevation of a 150M lb/hr factory assembled boiler designed to burn No. 6 oil superimposed on the side elevation of a stoker-fired boiler of the same capacity along with its coal bunker, dust collector, baghouse, and induced draft fan.

The rendition of one of our new powerhouses shown in figure twelve provides an even more striking comparison between coal- and oil-fired boilers.

Two 80M lb/hr pulverized coal-fired boilers with baghouses, coal pile, coal conveyor, railroad tracks and other supporting facilities occupy 90% of the scene. One 80M lb/hr oil-fired factory assembled boiler with its oil tank stack can be found in the foreground.

In cases such as this, "replacement" rather than "conversion" describes the action. A completely new coal-fired powerhouse is built at great capital expense and the factory-assembled boiler is either abandoned or retained as a standby.

The competition for capital is intense. Business managers must make tough decisions on whether dollars needed for new coal based powerhouses can be better spent on projects for energy conservation, improvement of product quality, expansion of production facilities, or building of plants to produce new products, etc.

The return on investment for one of our new coal-fired plants was maximized by sizing the boilers for a very high load factor. The capacity of the coal-fired boilers equals the base load required by the manufacturing plant and oil-fired boilers have been retained to handle load fluctuations as well as loads during overhaul of a coal-fired boiler.

At this plant cogeneration was evaluated and finally rejected because the plant uses steam at rather high pressure causing a poor net return on the incremental investment required for cogeneration. Nevertheless, the design pressure of the boilers installed is twice that of the steam pressure required by the plant and provision has been made for addition of superheaters so that we can take advantage of a cogeneration opportunity in the future when and if it can be justified.

Microprocessor-Based Boiler Controls

In addition to satisfying opacity and particulate emission limits, the stack effluent from our two newest powerhouses must not exceed .7 lb/MM BTU of NO_x. It has been well documented that the formation of NO_x can be reduced by reducing the peak flame temperature at the burner and by lowering the oxygen level in the burning zone. We will depend upon the boiler vendor's burner and furnace design to minimize the peak temperature in the flame, and we are employing a very sophisticated fuel flow/air flow combustion control system to deliver 5 to 15% excess air at the burners. Additional air required to complete combustion is admitted through ports midway up in the furnace.

Primary and secondary air admitted to the burners served by a windbox compartment will match the total flow of fuel to those burners. Total fuel will consist of coal plus possibly minor amounts of stabilizing oil. (see figure 13)

Coal flow is measured by a gravimetric feeder. The BTU content of the coal and, hence, the quantity of air required to complete its combustion will vary by plus or minus 10%. The combustion control system corrects for the variation in BTU content on line and applies this correction where necessary.

The boilers have oxygen analyzers for closed loop trimming control of secondary air admitted to the burners.

This unusual degree of complexity led us to choose a microprocessor-based combustion control system which can perform the arithmetic functions more reliably and accurately than can our usual pneumatic or electronic analog control system. The control room operator is equipped with CRT's and keyboards which he uses to observe and operate the boiler control systems.

This is our first experience with microprocessor-based combustion controls applied to a coal-fired boiler. One of the units is now in the start-up phase and we'll be in a better position to judge its effectiveness and reliability several months from now.

Burner Management System

Our 40 or so pulverized coal-fired boilers mentioned earlier have operated in the past, and continue to operate, with little or no automatic burner management. Gas ignitors, where used, are interlocked to prevent unburned gas from entering the furnace and the coal flame is sometimes monitored by a flame scanner, but the latter serves only as a monitor and alarms when it sees no flame. We depend upon the well-trained operator to shut down a pulverizer when an unsafe condition exists, and do it in such a way that a fire does not start in the pulverizer system. Our record of safety and reliability with this method has been excellent due to the attention given by well-trained operators.

However, the operating personnel in plants most recently converted to coal have been accustomed to firing gas and oil with complete flame safeguards, and preferred that their new coal-fired boilers be similarly equipped. We in Du Pont employ a supervised manual system rather than an automatic sequence system. The operator initiates all actions but is supervised along the way by flame scanners, limit switches, and other interlocks.

In keeping with our policy of using a supervised manual system for gas- and oil-fired boilers, we equipped the new coal-fired boilers with a remote manual sequence type control in which the control room operator initiates each sequence of the burner operation. Certain sequences can and must be initiated at the firing aisle.

Again we chose microprocessor-based burner management systems because the complexity of the logic sequences would have required installation of an unwieldy number of relays and timers.

We followed the National Fire Protection Association Standard Number 85E in our design of the system. In accordance with this standard a pulverizer trips upon loss of indication of flame at the burners served by that pulverizer, and the boiler trips requiring a timed purge before relight upon loss of all flame in the furnace.

We have equipped the operator with a complete window to see his powerhouse through CRT's and back-lighted pushbuttons in hopes that this will enable and encourage him to operate the facility at maximum efficiency. Two operators will man each shift with no shift supervision.

Boiler Subsystems

Each of the boiler subsystems such as coal unloading, sootblowing, baghouse operation, and ash handling is monitored and controlled by a programmable controller which seems uniquely capable of handling the routine sequences associated with this equipment. We have increased the sophistication and complexity of our control systems in one giant step. Time will determine the wisdom of our choice.

Future Plans

Our future tentative plans to increase coal's share of fossil fuel burned by Du Pont include the following:

- Test firing of a coal - water mixture into a field-erected boiler currently burning oil.
- Installation of a pulverized coal-fired Dowtherm vaporizer designed for the low furnace heat flux rate required in such a unit.
- Gasification of coal to generate gas burnable in small boilers and Dowtherm vaporizers currently firing natural gas and/or oil.
- Followup of work by others on flue gas desulfurization systems with particular interest in the potential for dry scrubbing as well as fluidized bed combustion.

Conclusion

Coal has the potential to become our major energy source to produce steam, thereby reducing our dependence on foreign oil, and we will continue to explore every opportunity to increase its use. However, the price of oil and gas relative to coal and our ability as engineers to design, build and operate cost effective coal-based facilities will determine the success in developing coal conversion projects that will be favored over other business ventures in the competition for capital.

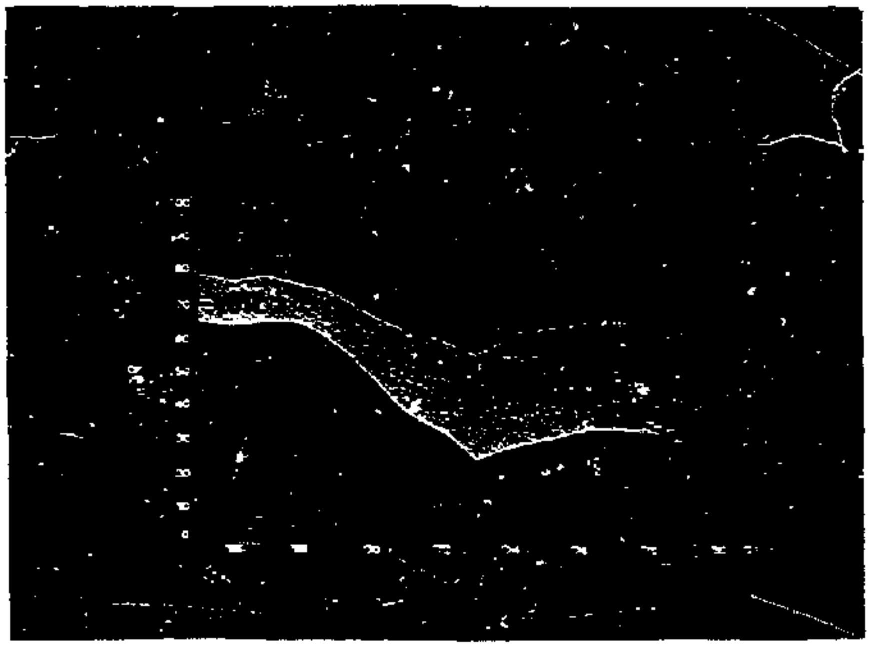

Fig. 1

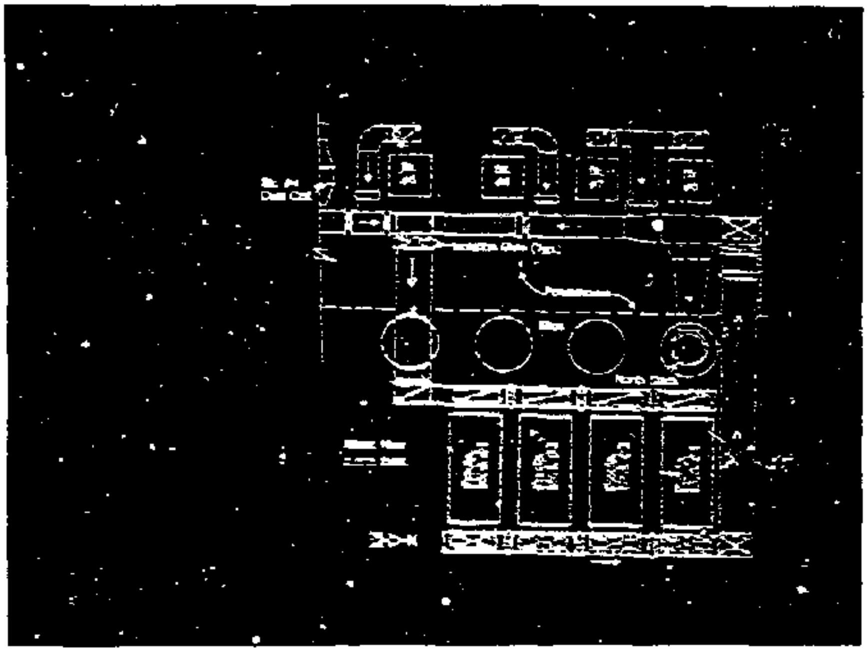

Fig 2

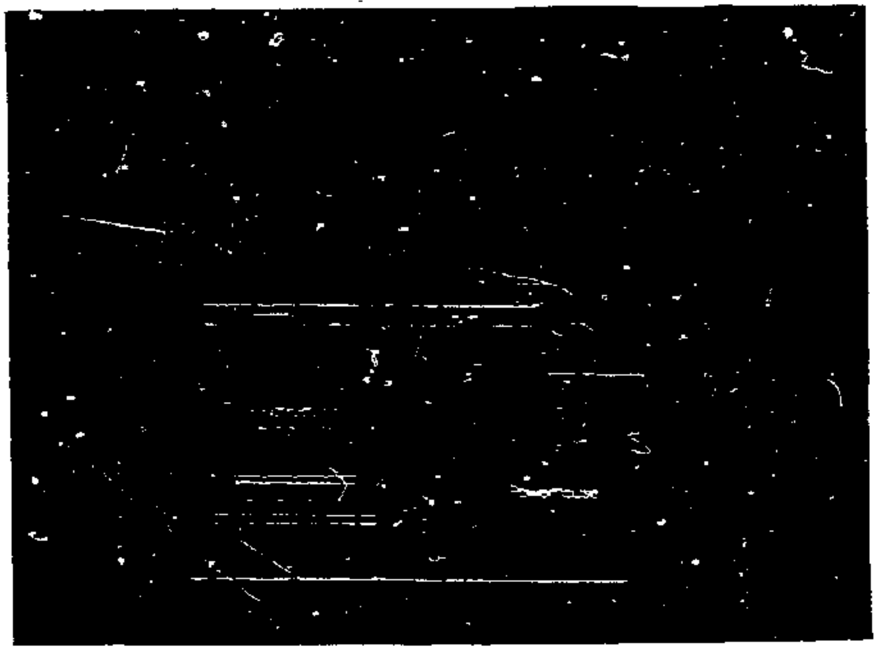

Fig 3

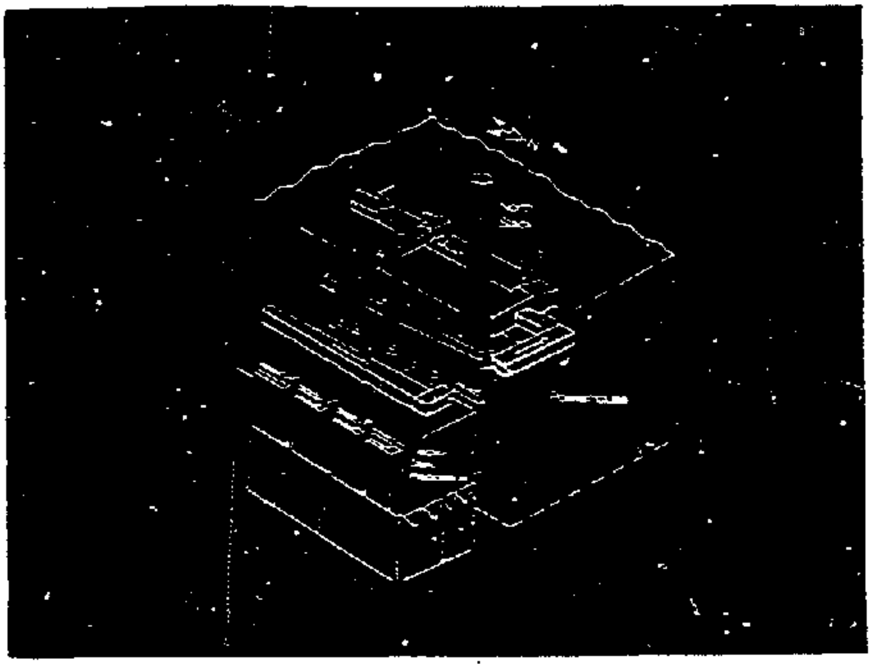

Fig 4

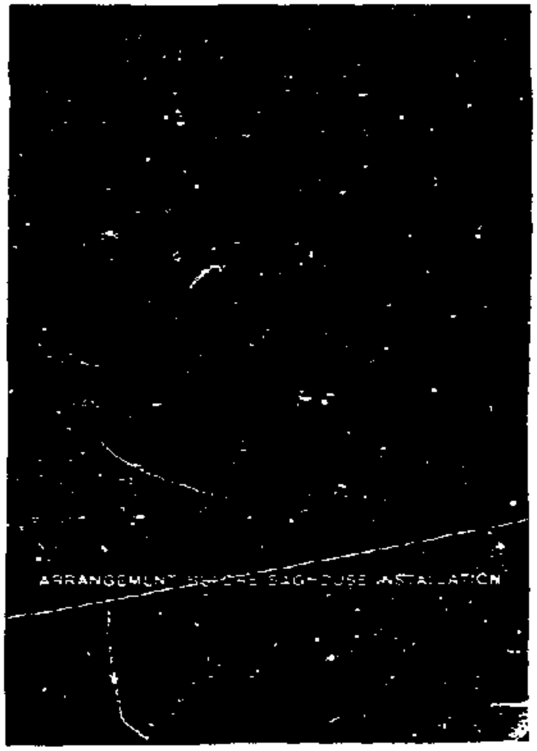
ARRANGEMENT BEFORE BAGHOUSE INSTALLATION

Fig 5

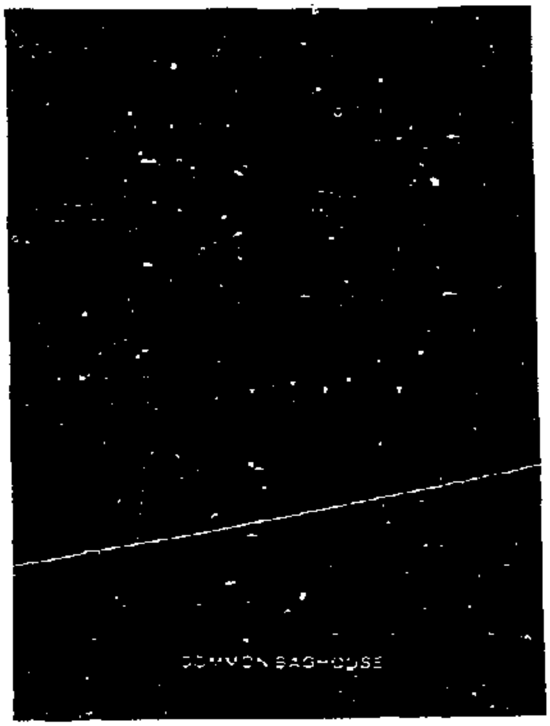
COMMON BAGHOUSE

Fig 6

Fig 7

Fig 8

Fig 9

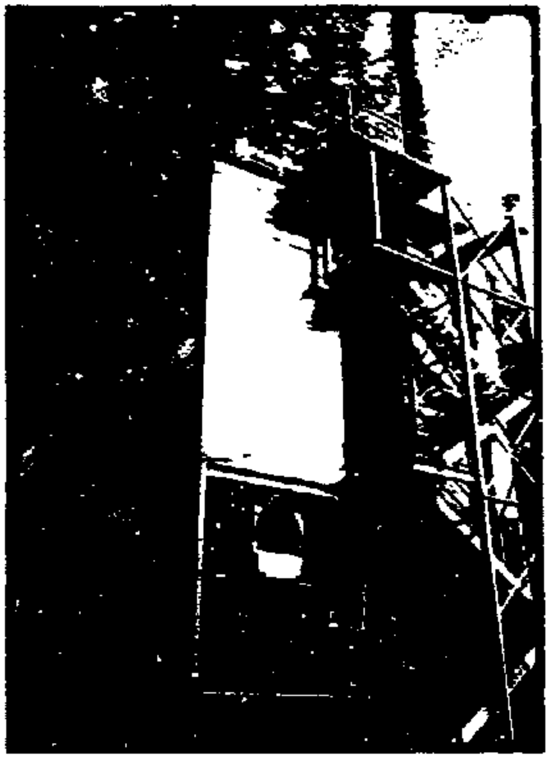

Fig 10

Fig 11

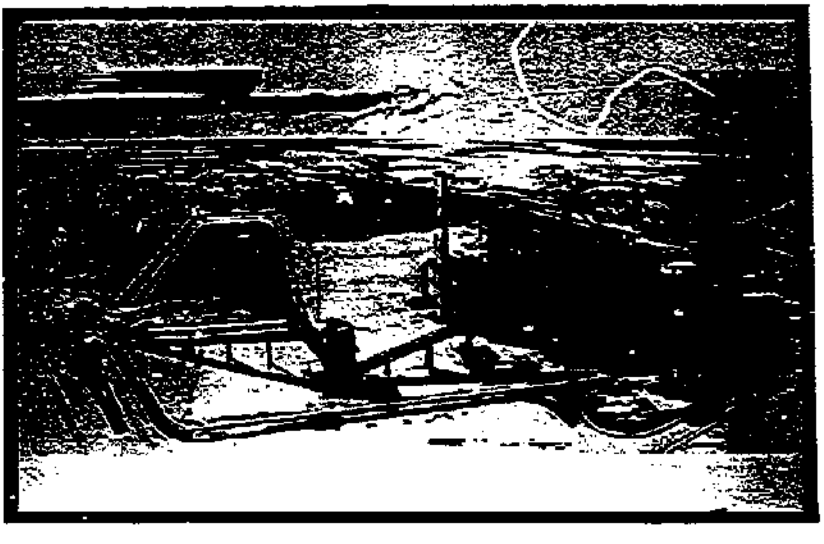

Fig 12

Fig 13