



TOGETHER
for a sustainable future

OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.



TOGETHER
for a sustainable future

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as “developed”, “industrialized” and “developing” are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

19685

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

Vienna, Austria

PROJECT No XA/RAF/90/602

ENGINEERING SERVICES

FOR ZIMBABWE GASIFICATION PROJECT

CONTRACT 91/060

as detailed in ANNEX B thereof

FINAL REPORT

*Submitted by
C E Haden, Chairman & Chief Executive*

*Cochrane Engineering (Pvt) Ltd
P O Box ST.361
Southerton
Harare
Zimbabwe*

November 1991

CONTENTS

<u>Section</u>		<u>Page</u>
1	Preamble	3
2	Plant Performances	6
3	Specification for Modified Plant	27
4	Diesel Engine Retrofitting	36
5	Electrical Generator	41
6	Instrumentation, Wiring and Controls	45
7	Typical Licence Agreement	48
8	Cost Estimates	56
9	General Comments	58
10	Drawings	

1 PREAMBLE

1.1 OBJECTIVE OF THE PROJECT

This project involves the setting up of a pilot gasification plant in Zimbabwe to test the viability of the technology for converting agricultural residues into mechanical or electrical energy for rural applications.

Since the fuels to be tested are not the established standard fuels for gasification, ie wood or charcoal, the pilot testing programme will establish the suitability of the agricultural residues in two standard gasifiers especially purchased for this purpose - one from SES S.p.A Roma of Italy and the other from Ankur Scientific Energy Technologies Pvt Ltd of India.

On completion of field testing a report will be compiled on the performance of the two plants, in respect of characteristics, design, modifications and ease of local manufacture, including local manufacturing cost and other relevant socio-economic information.

1.2 EQUIPMENT SELECTION

In an earlier phase of this project a technical representative from Cochrane Engineering (Pvt) Ltd was provided, at the request of UNIDO, to accompany the UNIDO selection team on its tour, world wide, to inspect small gasification units operating in the field.

The team assessed units operating on a variety of fuels, the established standard fuel being wood and charcoal. However this Project is particularly concerned with the testing of a variety of agricultural residues, which would include ground nut shells, coffee waste, macadamia nut shells, rice husks, sawmill waste, and maize cobs etc.

With this in mind the team would select two suitable gasifier units to be purchased, transported to Zimbabwe, and erected at Nijo Estates, for extensive field testing using the above-mentioned agricultural residues.

These objectives were achieved by the UNIDO team after a wide variety of gas producer plants were viewed under operating conditions with useful feed-back from the operating staff involved.

It was obvious that while some plants would perform on the fuels envisaged, others were not suitable.

The final selection for the purchase of one SES GE.40 gasifier from S.E.S. of Italy, and one ANKUR BG-40 from Ankur Scientific Energy Technologies (Pvt) Ltd of India was made and these plants were ordered for delivery to Zimbabwe towards the end of 1990.

1.3 PREPARATION FOR FIELD TESTING

The selected equipment arrived in Harare, Zimbabwe, towards the end of 1990 and Cochrane Engineering were involved in assisting the two commissioning engineers sent from the respective gasification manufacturers, together with the UNIDO representatives, Mr W J Ascough (Zimbabwean Project Director) and Mr L Palm, Chief Technical Adviser, in the erection and start-up of these two machines prior to the Christmas holidays at which time all parties returned to their home countries.

The electrical connecting of suitable farm appliances, ie drying fans and water pumping machinery, was made in order to supply a steady load for the gasifier generating plant during the testing phase which was to follow in the new year and to which the balance of this report is related.

2 PLANT PERFORMANCES

2.1 SES GASIFIER PLANT

2.1.1 The system as supplied by S.E.S. S.p.A. Roma

The SES model GE 40 gasification unit as supplied from the manufacturer is illustrated in Figures 2.1.1.a and 2.1.1.b. The unit consisted of the following components:

a) The Gas Generator

This is a down-draught type gas reactor, with a fixed fuel bed. The fuel was fed manually in batches at the top of the generator, and the ash is removed manually from the base of the unit. Air for partial combustion during normal operation by natural means enters just above the ignition zone, and thus the unit operates at near atmospheric pressure. The hot gas leaves the unit via two rectangular ports 180° apart. There is a dial thermometer (0-400° C) on each outlet port.

b) The Forced Draught Fan

A small centrifugal type fan provided combustion air for starting the process, and could be of a 12 V supply.

c) Bed type Filter

The hot gas from the generator passes through a filter bed that consists of metal swarf. This removes the large dust and soot particles from the gas. There are two identical units in the system and the gas is passed through them in parallel.

d) The (scrubber) cooler

The gas from the two filters passes through a concurrent water scrubber. Hot gas and water pass in parallel inside a set of finned tubes. There is a wire gauze at the bottom of each of the cooling pipes. Ambient air in cross flow is passed over the tube bank using a 0,37 kW, 380V axial fan. The cooling water is recirculated from a sump at the bottom of the cooler using a 1,5 kW 380V centrifugal pump. The water level is made up manually and can be checked by opening a gate valve. There is a dial thermometer in the water basin, and two mercury in gas thermometers in the gas stream on this unit. This unit removes small and medium sized dust particles in the gas stream, and the gas leaving it is saturated.

e) Disk type filter

The moist gas from the scrubber is passed in parallel through two sets of three disk filters in series.

These are cooled by a 0,37 kW, 380V axial type fan blowing over the six cylinders.

By changing the gas flow, excess water and fine dust particles are removed by this unit.

f) Bed type final filter

This is a large cylinder into which the gas passes into the bottom. Wood wool filter medium is placed on a grill support above the gas inlet and finally out of the filter. There is a drain to remove any condensate from the filter. Its large size reduces the gas velocity significantly and removes the majority of any remaining water and dust before the gas is passed to the generating set.

g) Gas ducting

The ducting between the gas generator and the mechanical bed type filter is in mild steel piping. All ducting between the other units described above is flexible and made of plastic over a spiral wound wire.

h) Flares

There is a flare on the gas generator off one of the rectangular ports and one just prior to the electrical generating set. These are used during start up and shutting down the plant.

i) Gas mixing valve

Gas and air are mixed by two valves that are linked by a turnbuckle for adjusting to set the appropriate air fuel ratio. This arrangement feeds the air and fuel to a carburettor specifically suited to producer gas.

j) Generating set

An internal combustion engine drives a brushless AC generator. Speed is controlled by a mechanical governor that is connected to the mixing valve linkage system.

k) The condenser moisture tank

On the gas reactor above the hot gas outlets there is a tank which allows vapour to condense. This unit collects tars that must be regularly removed from the system.

l) Control panel

In the panel there is a key switch to stop/start the engine. There is a stop button. The following instruments are used:

- 1 Oil pressure indicator 0-10 bar
- 2 Water temperature indicator 40-120°C
- 3 An ammeter for each phase 0-150 amp
- 4 Voltmeter
- 5 Kilowatt meter
- 6 Frequency meter 45-65 Hz
- 7 Hour meter

m) The batteries

On the engine/generator mounting frame there are located two 12V batteries. There is a battery charger included to charge the batteries during normal operation. During start up the batteries provide essential power for the forced draught fan.

2.1.2 Initial Test Results

2.1.2.1 Specification of the plant by SES

- a) Fuel to be used
 Fuel size: 50 x 50 x 50 mm
 Fuel types: Wood (recommended)
 Corn cobs
 Mixtures of other agricultural
 residues with the above
 Moisture content: 15-25%
- b) The power capacity
 Maximum capacity 40 kW
 Rated capacity 35 kW
 Note: These capacities are with dry wood
- c) The Generator
 Rated fuel input 1,3 kg/kWh
 Rated gas output 120 Nm³/hr
 Rated gas cv Not stated
 Thermal efficiency 75-80%
 Energy 0,410 GJ/hr
 Turn down ratio 1:3
 Hopper capacity Not stated
- d) Pressure drops
 Rated pressure drop 600 mm water gauge
 Maximum allowed 1000 mm water gauge

2.1.2.2. Test Results and observations

This report will only deal with the results of corn cob firing as tests with other local agro-waste residues indicated that they were not suitable for firing on both the SES and Ankur units.

Corn cobs have the following typical characteristics:

Diameter	30 mm
Length (cut into 3 pieces)	40-60 mm
Volatiles	80,2% m/m
Fixed carbon	16,2% m/m
Ash	3,6% m/m
Carbon	45,31% m/m
Hydrogen	7,16% m/m
Gross calorific value	15,58 MJ/kg
Bulk Density	130 kg/m ³

A sun-dried sample usually contains about 6% moisture. Samples tested varied from 10-15% moisture.

Specific useage of the fuel varied from 1,4 kg/kWh at high loads, to 4,1 kg/kWh at low loads (about 25 to 30 kg/hr of corn cobs).

The gas composition was typically

Carbon monoxide	18,0% v/v
Oxygen	1,5% v/v
Carbon dioxide	10,5% v/v
Hydrogen	Not measured
Volatiles	Not measured

The gross calorific value of this gas would be 2,2 MJ/m³ at STP (neglecting the hydrogen).

Dust in the gas was less than 7 mg/Nm³ and there were no tars present after the gas was filtered

Inspection of the charcoal bed has established that this is not self generating for sustained continuous firing. Charcoal is required in the bottom section of the reactor, at about 0,08 kg/kWh. No slag is formed but evidence of channelling has been observed. There is also evidence that the fuel hopper lid does not seal, and thus leaks air.

The tests and results with the SES gasifier as supplied were generally acceptable. Some general comments are:

- a) If the generator is not poked or agitated the fuel bed channels and the resulting gas quality is poor.

- b) If the filter system fails, dust levels rise unacceptably and will accelerate wear in the diesel engine
- c) The operator can be exposed to dangerous levels of carbon monoxide when filling the fuel hopper or lighting the flares.
- d) The water levels in the scrubber if not maintained lead to hot gas burning the wood-wool in the final filter, and unacceptable levels of tar and dust in the gas supply to the engine. Hot gas would also contribute to early failure of the plastic hoses.
- e) The corn-cob fuel is too long and needed to be cut into three pieces manually. The cobs as received cause bridging of the fire. If cut too small very high pressure drops are likely.
- f) The flexible pipes are not sufficiently durable and airleaks have lead to explosions.
- g) The gas/air mixing valve linkage is subjected to vibration

2.1.3. Modifications made to the plant

- a) A safety cloth type filter was added to the filter system between the wood-wool filter and the air/gas mixing valve. This was a small unit that was considerably easier to clean than the final bed filter. Regular cleaning gave a rapid indication of the performance or lack thereof of the whole filtering system.
- b) The fuel storage capacity within the generator was insufficient. The upper part of the generator was extended by 150 mm, and the diameter reduced from 650 to 430 mm. To complete this modification satisfactorily there is an inner jacket made of perforated plate which was extended with 15 mm square wire mesh. The wire mesh used was an improvement on the original design as the perforated plate was prone to clogging with tars.
- c) The hopper lid leaked, and this caused minor explosions in the reactor shortly after starting the engine. The lid design was modified to use a flat rubber gasket and sealing is now adequate. It should be noted that this lid is spring loaded to allow relief in the event of an explosion in the reactor.

- d) A power meter that measured kilowatt hours was added to the control panel.
- e) Drain valves were added to the disc type filters to drain water during operation
- f) The flare valve was raised on the generator to just above the top hopper lid.
- g) Various pressure point tapplings were added to measure the pressure drops across the filter section units.

2.1.4 Future modifications

Detailed recommendations are specified in section 3 of this report, but in general are as follows:

- a) Pipe the flare to a safe position
- b) Protect the flare flame from strong winds
- c) Make the reactor condenser larger
- d) Reduce the duplication of the filtering system to reduce cost
- e) Extend the fuel loading platform to allow the operator to fill the generator hopper from a position that is upstream of the wind.

- f) Allow for fuel bed agitation to prevent channelling
- g) Use a nozzle over the air inlet pipe to the combustion zone that would prevent back pressure from giving a dangerous flame from this pipe.
- h) Use steel pipes to replace the plastic flexible hose
- i) Simplify the filter system
- j) Add a final filter (gauze) just prior to the gas/air mixing valve, that clogs rapidly in the event of failure in any part of the filter system.

2.1.5 Manufacturer's drawings

The manufacturers drawings were made available at the time of writing this report and certain assumptions have been made in regard to metal thicknesses and internal component sizes if not suitably detailed on the drawings supplied.

2.1.6 Operation Time

The plant as at 25 September 1991 had operated for 780 hours. On an eight hour per day shift this is only three to four months operating experience.

Long term problems which may develop with a extended running have not been fully established at this stage.

Tests on the engine oil carried out by ZEMCO (Pvt) Ltd indicate that engine wear is minimal, as would be expected given the length of service.

2.2 ANKUR GASIFIER PLANT

2.2.1 The system as supplied by Ankur Scientific Energy Technologies Pvt Ltd of India

The plant is as follows, and is illustrated in Figure 2.2.1

a) The Gas Generator

This consists of a gas reactor with a conical fuel feed hopper. Air for partial combustion is fed through nozzles in the fuel hopper. The generator has a water seal at its base.

b) Hot Gas Cyclone

A ter Linden type cyclone is on the hot gas discharge of the generator. The discharge is sealed and opened for cleaning when the plant is shut down.

c) Venturi scrubber

The gas is scrubbed by passing through a scrubber with water being pumped through the venturi, with a small centrifugal pump.

d) Separator

The water and moist gas are passed through a separator which also contains a cloth filter element of about 10m^2 .

e) Booster Fan

The gas from the separator is boosted in pressure to be supplied to the engine using a centrifugal fan.

f) Flare

The flare is used to burn gas when the engine is not in use and is immediately after the booster fan.

g) Air Filter

An air filter is used to clean combustion air, and the air supply and gas supply are controlled by manually adjusting two valves.

h) Engine Alternator

The engine alternator set generates the electrical power

i) Diesel

The engine is operated on a fuel mixture of gas and diesel oil.

2.2.2 Initial Test Results

2.2.2.1 Specification of the plant by Ankur

a) Fuel to be used

Fuel size:	10 mm minimum 125 mm maximum
Fuel type:	wood/wood waste cotton stalks coconut shells maize cobs
Moisture content:	5-20%

- b) The Power Capacity
 Rated capacity: 40 kW
- c) The Generator
 Rated fuel input 40-48 kg/hr
 Rated gas output 100 m³/hr
 Rated gas GCV (average) 4.18 MJ/m³
 Thermal efficiency 70-75%
 Energy 0,418 GJ/hr
 Downturn ratio 1:3
 Diesel replacement 65-75%
 Hopper capacity 200-300 kg
- d) Pressure drops Not Stated

2.2.2.2. Test results and observations

Tests with 100% diesel use indicated that fuel consumption was high when compared with typical performance with engines elsewhere in the world. Diesel substitution was considerably lower than quoted, and involved frequent adjustment of the manual throttling valve. Diesel substitution of 46-50% was achieved. However with the frequent changes required of the throttle valve, in practice a lower diesel substitution is quite likely.

Specific fuel consumption was about 1,0 kg/kWh at high loads and 2,2 kg/hr at low loads (about 20 kg/hr of corn cobs).

The gas composition was typically

Carbon monoxide	11,6% v/v
Carbon dioxide	4,6% v/v
Hydrogen	not measured
Volatiles	not measured.

The gross calorific value of this is 1,4 MJ/hr³ at STP (neglecting hydrogen, methane etc).

Dust in the gas was 80-200 mg/Nm³ and no tar was present in the gas beyond the filtering system. This dust content is higher than the recommended 10 mg/Nm³ limit.

The plant was not suitable as supplied and initially tested. The problems encountered are as noted:

- a) The gas generator firebars would become clogged when firing on corn cobs
- b) The vibrator agitated the fire too severely and would cause the fire bed to collapse
- c) The lid was difficult to open and close
- d) The charcoal bed could not be accessed
- e) The pits were not made with sloping sides at one end, so cleaning was extremely difficult.

- f) The cyclone manufacture caused a high pressure drop
- g) The venturi cone was too rough
- h) The requirement of a relatively high pressure water pump for the venture means power is required for its operation
- i) The gas is not adequately filtered, and contamination will lead to long-term engine problems, and a requirement for frequent maintenance.

In general this system uses more diesel than a well designed unit would when fired on a fuel mixture, which defeats the object of using gas. The poor filtering of the gas cannot be tolerated without rapid wear of the diesel engine.

2.2.3 Modifications made to the plant

a) Operation

The vibrator was used intermittently and this prevented the firebed from collapsing whilst giving the benefit of agitating the bed, thus replenishing the charcoal bed. Continual use of the vibrator, even with a small eccentric mass, caused the fire bed to collapse.

b) Separator

The separator was doubled in length and a cloth filter added which improved the separation and the gas cleanliness. The cloth, however, on becoming wet, lead to very high pressure drops which prevented running of the engine after short periods of 3-4 hours.

c) Filter

A final filter of a bed type and using wood-wool as a medium, was installed between the blower and the engine.

Even with these modifications there was difficulty with operating the generator and with dirty gas, thus the unit is not the preferred choice.

2.2.4 Future Modifications

a) Generator

- Cone angle could be changed to prevent blocking of the firebars
- The vibrator could be replaced by a mechanical de-ashing device capable of manual activation in such a way as to agitate the bed
- The fuel lid should be modified to improve operation

- A side port must be added to allow replacement of the fire bed without opening the hopper lid

b) Gas Cleaning Equipment

- The cyclone should be designed to give a small pressure drop
- The venturi should be designed to give an increase in gas pressure
- The filter/separator design must be improved to provide clean gas for use with the engine.

c) Engine Start

It should be possible to start the engine with petrol so that battery power is not required to run the booster fan and venturi pump.

d) Layout

The sumps should have one sloped side to allow for easier regular cleaning.

2.2.5 Manufacturer's Drawings

The manufacturers drawings were not available at the time of writing this report.

2.2.6. Operation time

The plant has been tested for 500 hours as at the 25 September 1991 and the wear to the engine at this stage should be minimal. However oil analysis carried out by ZEMCO Private (Limited) indicate that the wear metal components tested in the engine oil are above normal. This is in line with the fact that high dust carry over occurred with the filter system.

The period of testing based on an eight hour per day shift amounts to only two months continuous operation. This is about half of the accumulated experience gained with the SES plant.

3 SPECIFICATION FOR MODIFIED PLANT

With the experience gained from the project and field testing, several changes to the plant should be considered.

It is important to realise the full implications of any changes made to the equipment. Changing any one item of a system has corresponding effects on other pieces of the plant in the system. For this reason the benefit of any of the proposals detailed in this section should be subject to further testing - it would be unwise to produce units based on these proposals without further extensive field trials.

The proposals described here are based on the experience that the SES machine was more suitable and provided superior results.

3.1 GENERAL DESCRIPTION OF PROPOSED PLANT

The proposals are given in the layout of figures 3.1.a. and 3.1.b

It is apparent that this would easily fit into the same area as the SES gasifier plant at Nijo Estate. In general the proposal uses the SES generator, and a revised gas cleaning system.

The hot gas passes through a simple concurrent heat exchanger. From this it is passed through a ter Linden type cyclone. In practise about 70% of the dust in the gas would be collected in this unit.

From here the gas is passed through a vertical venturi scrubber into a separator tank. Cooling water is circulated through the venturi from the bottom of the separator. The gas from the separator is then directed to the outer shell of the heat exchanger. This attempts to evaporate any water still in the gas from the separator. The heat exchanger can be bypassed to prevent the gas from overheating and is passed to a filter of similar outer dimensions to the SES final bed filter. Lastly, the cold clean gas is passed through a filter separator placed as close to the engine air/gas mixing valves as possible.

The advantages of this proposal are as follows:

- a) The gas system is simple and from the field tests it should be effective.

It uses the generator technology which has been proven but provides a simpler, more easily maintained gas cleaning system.

- b) There is no duplication in the gas cleaning system so it should be cheaper to manufacture. It would be possible to provide two filters in parallel if continuous service was required. This would permit filter changes during operation, so that one filter would be on standby.
- c) Two fans have been removed thereby improving the amount of power available. The SES plant as supplied can provide 35 kW of power at its rated capacity. However the gas plant requires 2,24 kW to run and thus the net power is only 32,76 kW.
- d) The control of the gas temperature before the gas entering the final filter will give a longer life to the wood wool. This will prevent the wood wool being wetted and rapidly deteriorating as a result.

Two factors which should be remembered when considering these proposals are:

- i) The pressure drop in the system may be larger and further tests are essential to establish the performance of the proposal

for the pressure drop across the new gas cooling and cleaning equipment.

- ii) The cooling water may overheat and a simple cooling water system would have to be added if the separator area was found to be inadequate.

3.2 INDIVIDUAL DETAILS

3.2.1 The generator

- a) There should be provision of some means of agitating the generator so that the combustion air does not cause the fire bed to channel and the quality of gas to deteriorate. It is proposed that a suitable modification be added to the SES drawing of the generator.

One idea is to connect the engine frame to the generator base on site thus making use of the engine vibration. It must however be remembered that this could also cause the firebed to collapse. In these circumstances there would be no way for the operator to control it. A manual means of agitation is preferred as it can then be controlled by the operator.

- b) A single gas outlet is used, though it would be a relatively simple matter to connect pipes to the two outlets into a single gas duct. The position of the outlet and its effect on the gas quality should be checked. In view of the change the impact on the length of operation with one fuel charge should be investigated.
- c) A platform that allowed access to at least 200⁰ of the generator would be advisable; however, how this would affect other routine operations should be considered. Another solution would be to make the ladder and platform smaller but more mobile. This would make it easy to position for the safest place in relation to the wind for fuel feeding.
- d) Both flares should be piped to a safe place, preferably above the roof, and a ladder used to light the flare. This arrangement would be safer from the point of view of gas poisoning and also would limit the possibility of fires. A typical flare is detailed in Figure 3.2.1.a
- e) A larger condenser should be fitted to the generator to collect more of the tar condensates. Some method of burning or discarding this condensate should be identified.

- f) Of some importance is the method of preparing the fuel. Whilst being labour intensive, the manual chopping was technically acceptable. A more rapid means of preparing the fuel would be more convenient. A larger model of gasifier could possibly utilise local cobs without the need to reduce their size. The added capital cost compared with the decreased operating labour may prove an acceptable alternative.

The fuel should be allowed to air dry, at the least, and should be properly managed.

- g) The generator combustion air nozzle should be protected to prevent flames emitting from this port. Such protection could be obtained by placing a deflector plate in front of the nozzle when removing the forced draught fan after start up.
- h) The final fabrication should be stress relieved after welding. This should reduce the attack of the heat affected zone of the welded areas which in the SES plant resulted in pin-hole leaks due to the corrosive nature of the gas.

3.2.2 The Heat Exchanger

This is a single pass concurrent shell and tube unit. The hot gas is cooled by the cooled gas stream from the separator. The heat exchanger is illustrated in Figure 3.2.2.a

3.2.3 The cyclone

The ter Linden cyclone (see Figure 3.2.2.a) collects the dust from the hot gas into a sealed can. It can be collected in a simpler water trough, which provides a water seal at the outlet.

3.2.4 The scrubber

A venturi is used to scrub the gas with water. The design is based on a throat velocity of 35 m/s which has an efficiency of 98% in removing dust particles of 2 microns in size. This unit will effectively remove the tars from the gas. The scrubber is detailed in Figure 3.2.4.a

3.2.5 The separator

The gas water mixture enters the separator which collects the water at the bottom. It allows the gas to separate and pass out the top. The water trough at

the base can be cleaned from the side and provides a reservoir for the venturi. The separator is detailed in Figure 3.2.5.a

3.2.6 The filter

The cold gas is now passed through the shell side of the heat exchanger to the final filter. The internal arrangement of the proposed filter is given in Figure 3.2.6.a. This includes a separator base section to remove any water or condensates from the gas. Two baskets that carry wood wool are situated for easy replacement of the filler media. An external davit provides access for removing the baskets to replace the wood-wool filter material. Tests with coke, corn-cobs and local elephant grass all proved unacceptable filter media.

3.2.7 The safety filter

A final cyclone moisture pot is provided just before the gas air mixing valve. The discharge of this unit has a stainless steel gauze in it that will clog rapidly with dust particles. This will provide safe operation of the engine as it will give a high pressure drop every time the cleaning equipment fails. The gauze should have a tab on it so it is easy to identify that it is in place. This is illustrated in Figure 3.2.7.a

This unit has a spring loaded exit to allow for minor explosions and a drain to remove any condensate. The discharge connection is a flexible rubber hose for connection to the engine.

3.2.8 The gas air mixing valve

The butterfly valves should be of durable material as the one at Nijo Estate on the gas supply is very badly corroded. The linkage levers should be connected to the shafts that are split and have locking screws. These levers should then be connected by SKF rod ends with spherical bearings to provide an effective joint that will not vibrate loose. The turnbuckles must be adjusted against springs to prevent vibrating loose during operation.

3.3 SITE AND LOCATION

The area required is indicated in Figure 3.2.a. The area must as a minimum be protected from rain. A lock-up shed for storing tools and instruments will be needed. In general the plant area must be open, for good ventilation, with one side walled to cut down problems associated with strong winds.

Appropriate low power lighting should be considered for night operation if this is required.

4 DIESEL ENGINE RETROFITTING

4.1 INTERNAL COMBUSTION ENGINE

The following specification is proposed for the diesel engine to power the electrical generator set:

4.1.1 Specification

Engine type	:	4 stroke Otto cycle
Original type	:	Fuel diesel engine
Aspiration	:	Naturally aspirated
No. of cylinders	:	Six
No. of inlet valves	:	One per cylinder
No. of exhaust valves	:	One per cylinder
Total cylinder displacement	:	8,102 litre
Make	:	Fiat IVECO or similar
Maximum power rating:	:	71 kW at 1500 rpm with diesel fuel, steady operation

4.1.2 Modification necessary to convert the diesel engine from diesel fuel to producer gas

Compression ratio

modifications : From 17:1 to 11:1

Ignition : Spark plugs fitted in place of injectors with suitable adaptors

Distributor fitted in place of diesel fuel injector pump

Governor : Unless engine is supplied for stationary operation with governor fitted, a suitable governor with external lever is required

Gas/air mixture : A suitable air/gas carburettor is fitted on the air inlet section of the intake manifold

Starting carburettor: A small starting petrol carburettor is required for start-up purposes only.

Diesel engines having the aforementioned specifications, are suitable for modification to operate on producer gas.

The pistons and cylinder head require modifications to alter the compression ratio from 17:1 to 11:1, this being achieved by machining the piston heads and the combustion chamber shape in the cylinder head.

The existing diesel injectors are replaced with petrol engine spark plugs fitted to special adaptors and retained in the cylinder head by the same clamping arrangements as used for the diesel injectors.

The diesel fuel injector pump is removed and a six cylinder distributor head is fitted in its place, driven by the same pump drive shaft which also drives the governor.

The air inlet is fitted with the special gas/air carburettor for operating on producer gas with a small petrol carburettor for easy starting (which is necessary in areas where battery recharging is difficult).

These modifications are carried out for SES in Italy on Fiat engines by Messrs Gruppi Electrogeni, who provide the engine guarantee for such modifications with an engine life of 30 000 hours between overhauls.

This modification information is also available from a company also involved in diesel engine modifications, namely

Tessari S.p.A.
25 Viola
10133 Torino
Italy

With the necessary technical specifications, there are a number of automotive companies in Zimbabwe who could undertake this work, the most well-known of which are:

Incar Zimbabwe (Pvt) Ltd (Fiat agents)
P O Box 3097
100 Seke Road
Granitesite
Harare
Zimbabwe

Leyland Zimbabwe Ltd (Leyland agents)
Leyland Manufacturing Zimbabwe (Pvt) Ltd
P O Box 1762
28 Samora Machel Avenue
Harare
Zimbabwe

Cummins Zimbabwe (Pvt) Ltd (Cummins agents)
P O Box ST.363,
Southerton
72 Birmingham Road
Workington
Harare, Zimbabwe

Mike Appel Harare (Auto engineers and rebuild
P O Box 887 specialists)
Cor Seke & Kelvin Roads
Harare
Zimbabwe

Geoff's Motors (Pvt) Ltd (Engine reconditioning
6 Park Street specialists)
Harare
Zimbabwe

The engine selected must be complete with its cooling system incorporating a suitably sized tropical radiator, engine driven cooling fan and water pump, and alternator and oil cooler.

The engine and electrical generator are mounted on a common bed frame, with the engine being resilient mounted, and coupled to the electrical generator by a flexible coupling.

The engine governor is connected by a suitable crank linkage to the gas/air carburettor, which must regulate the engine speed under changing load conditions.

Easy access to all sides of the engine and electrical generator equipment is required, for servicing purposes and repairs.

5 ELECTRIC GENERATOR

5.1 GENERAL SPECIFICATIONS

On the two plants tested the two generators were significantly different, one being of the synchronic three phase model at 380 V 50 Hz with brushless AC excitation as fitted to the SES machine, while the Ankur machine had a revolving armature slip ring type self-regulating and self-exciting. Both are of 40 kW rated output and have performed satisfactorily. The generators should be selected on the ease of availability and back-up service relating to spares and replacement parts, and should generally comply to the following specifications:

Frequency	:	50 Hz
Minimum output	:	40 kW at 380 volts 3 Ph 50 Hz 50 kVa
Speed	:	1500 rpm
Type	:	Horizontal foot mounted
Code	:	Manufactured to BS2613 OF 1970, BS800 of 1954 and BS822 Part 6 of 1964, or equivalent
Bearings	:	Fully sealed ball bearings

Insulation : Impregnated for use in tropical climates

Coupling : Bare shaft machine suitable for direct coupling to the diesel engine via a flexible coupling

Voltage

Regulation : Capable of maintaining a terminal voltage within $\pm 2 \frac{1}{2}$ percent at all power factors between units to 0,8, being fully self-regulating and self-exciting.

5.2 LOCAL MANUFACTURE OF ELECTRIC GENERATORS

5.2.1 The capabilities for the manufacture of suitable electrical generators in Zimbabwe was established during the survey conducted prior to the production of this report.

The Harare area only has been targeted, and it has been established that two companies have the facilities and background knowledge to produce such machines, and one company is already manufacturing two models of generators.

Messrs L H Marthinusen (Pvt) Ltd, P O Box 1679, Douglas Road, Workington, Harare, Zimbabwe, who are a subsidiary of GEC of the United Kingdom, have a large motor repair facility, manufacturing transformers and undertaking repairs to large rotation machines.

Messrs Relmo Electric Motors, P O Box 2634, Cor Cripps and Kelvin Rds, Workington, Harare, are a division of Mashonaland Holdings Ltd, and are the local manufacturers of a range of induction motors built to the relevant British Standard.

Both companies have indicated their interest in the manufacture of electrical generators providing the quantity is considered satisfactory and the said manufacture would be based on an existing design which could be made available to them without the company entering into any Research & Development for this type of product.

It is felt that for the Project being assessed, this could be an expensive route, as there would be the initial pattern and machining set-up costs usually incurred when setting up a new product line which always affect the price of the final product.

- 5.2.2 Messrs South Wales Electric (Pvt) Ltd in Harare, who are part of the Hawker Siddeley Group in the United Kingdom, are already manufacturing a range of AC generators in Zimbabwe, these being 28 kW and 44 kW

machines. These are built to an established design within the Group, and a full technical specification is attached. These machines are already in production and are being supplied to the public for electricity generation.

It is recommended therefore, that should any gas producer manufacture in Zimbabwe and for the PTA region take place and should this manufacture involve the supply of diesel engine and electrical generator sets, we should use the South Wales Electric machine

South Wales Electric (Pvt) Ltd
P O Box 3095
Plymouth Road
Southerton
Harare

6 INSTRUMENTATION, WIRING AND CONTROLS

6.1 ON THE GAS PLANT

The following parameters should be indicated to assist the Operator:

Temperatures

- | | | |
|----|---------------------------------|---------------|
| a) | The hot gas temperature | 0-600 Celsius |
| b) | The cold gas temperature | 0-100 Celsius |
| c) | The separator water temperature | 0-100 Celsius |

Pressures

- | | | |
|----|---------------------------------|----------|
| a) | Filter inlet pressure | 0-10 kPa |
| b) | Filter exit pressure | 0-10 kPa |
| c) | Hot gas generator exit pressure | 0-10 kPa |

The Operator should have the following instruments:

- a) Draeger tubes for carbon monoxide and the appropriate gas sampling equipment
- b) Scale for weighing the fuel

6.2 OXYGEN

For safety purposes it is important that oxygen is available with which to treat individual who might become poisoned by the gas.

6.3 THE GENERATOR AND ENGINE

A typical panel layout is shown in Figure 6.1.a., and a wiring diagram in Figure 6.1.b. It is preferable to mount the panel against a wall, or on an independant stand, and not on the engine base frame.

The following minimum controls are recommended:

a) Low oil pressure switch

A low oil pressure switch should be fitted to prevent damaging the engine due to loss of lubrication, wired to immediately stop the engine.

b) Over-speed control

A means of measuring the speed on the governor should be included to prevent an overspeed condition occurring, which would immediately stop the engine.

c) Cooling temperature control

A high temperature switch should be fitted to prevent the engine overheating.

Each of the above controls should sound an audible alarm and stop the engine immediately.

A battery charger should be included for start-up power and ancillaries for the gas plant.

The following minimum instruments are recommended:

- i) Oil pressure indicator
- ii) Cooling system temperature
- iii) Phase ammeters (one for each phase)
- iv) Line voltage meter
- v) Frequency meter
- vi) Hours operated meter
- vii) Power meter
- viii) A kilowatt meter (an optional extra).

The Operator should have:

A Fyrite hand gas analyser for carbon dioxide. This would assist in the correct setting of the air:fuel ratio by carrying out tests on the engine exhaust gas.

TYPICAL LICENCE AGREEMENT

LICENCE AGREEMENT

between

SES S.p.A. ROMA

(hereinafter referred to as SES)

and

COCHRANE ENGINEERING (PRIVATE)LIMITED

(hereinafter referred to as CENG)

WHEREAS :

- A. SES has designed, developed and manufactured small gasification equipment to convert agricultural residues into electrical energy in respect of which it is the holder of several patents and has sole title to all designs and know-how;
- B. SES has granted a sole and exclusive licence to CENG to manufacture their gasification equipment designed by SES (" the products ") in Zimbabwe and to sell the products in Zimbabwe and SADCC (Southern African Development & Coordinating Council) countries (Zimbabwe and the said countries are referred to together as " the territory ").

NOW THEREFORE IT IS AGREED :

1. LICENCE

SES hereby grants to CENG a sole and exclusive and non-transferable right to manufacture the products within Zimbabwe and to sell the products in the territory.

2. DESIGNS

2.1 CENG acknowledges that all designs, specifications, plans and know-how supplied by SES will remain the property of SES and that CENG will acquire no rights therein other than the right to manufacture the products in terms of its licence.

2.2 CENG will hold in confidence all information which it receives from SES regarding the manufacture of the products and undertakes that :

2.2.1 It will take all reasonable steps to ensure that the said information will not be disclosed to any unauthorised party; and

2.2.2 it will not use any of the said information otherwise than for the purpose of manufacturing the products.

2. DESIGNS contd

2.3 CENG undertakes not to contest or attack, either directly or indirectly, the validity of any SES patent and it further undertakes that it will inform SES of any infringement of those patents which comes to its notice.

3. IMPROVEMENTS

3.1 CENG shall inform SES of all improvements and new designs made or developed by CENG during the term of this agreement pertaining to the products.

3.2 The provisions of this agreement extend to and include not only designs and know-how available to SES at the date of signature hereof but also to all subsequent inventions, improvements and new designs pertaining to the products.

4. INFORMATION AND ASSISTANCE TO BE SUPPLIED TO CENG

4.1 SES shall convey to CENG such drawings, designs and specifications as may be reasonably required to enable CENG to manufacture the products.

4.2 All manufacturing information of whatever nature originating from SES will remain the property of SES.

5. RESTRICTIONS OF MANUFACTURE AND SALE

5.1 During the terms of this agreement, CENG shall not develop, manufacture or sell any small gasification plant used for the production of electrical energy other than these products.

5.2 CENG shall manufacture the products in Zimbabwe for sale in the territory and any other export market agreed upon by SES.

6. QUALITY CONTROL AND NAMEPLATES

6.1 CENG shall ensure that the products manufactured by it are checked before they leave its works and that they conform to the engineering standards of SES and any drawings which SES may have supplied in respect of such products.

6.2 CENG shall permit the representatives of SES at all reasonable times to observe and inspect the manufacture of the products and to direct corrections in procedures and operations with a view to ensuring that the standard of quality, engineering, material and design for all the products shall be equivalent to those established and maintained by SES.

6.3 CENG will affix a nameplate in a conspicuous position on each of the products manufactured by it showing the name SES/CENG ZIMBABWE.

7. LIABILITY

CENG shall be responsible for all manufacturing and quality control liabilities and SES shall be liable to and shall indemnify CENG for any claims against CENG arising from defects or failures in design.

8. SALES

8.1 SES shall not grant any other licence or right to manufacture and/or sell the products in the territory.

8.2 Any enquiries which CENG may receive in respect of the products shall be dealt with by CENG in conjunction with SES and SES shall refer to and deal in conjunction with CENG with any enquiries which may be received from the territory in regard to the products.

9. ROYALTIES, FEES

CENG shall pay to SES a royalty of % and certain fees (these to be agreed but may not be more than 5% of the ex Works Price).

10. DISCLOSURE

CENG shall furnish to SES upon request :

10.1 The full terms of each contract which it enters into in respect of the products, including a copy of the contract documents.

10. DISCLOSURE contd

10.2 An itemised statement showing the manner in which it arrived at the contract price, transport to the place of erection and the cost of erection and commissioning.

10.3 A detailed record of all payments made by the customer showing the date and amount of each payment.

11. TERMINATION

Either party may terminate this agreement upon giving three months notice of termination to the other party.

12. EFFECT OF TERMINATION

Upon termination of CENG's licence, CENG shall immediately :

12.1 Hand over all drawings, specifications and other documents relating to the manufacture of the products to SES.

12.2 Cease to use the technical information and patents relating to the products.

12.3 Cease manufacturing, dealing in or selling the products.

EXCEPT in each case as may be necessary to complete orders which were in hand on the date of termination.

12. EFFECT OF TERMINATION contd

The royalty and fees referred to in 9 above shall remain payable in respect of such orders notwithstanding the termination of this agreement.

In addition SES shall notwithstanding the termination of this agreement remain responsible for its obligations in terms hereof in respect of the completion by CENG of such orders which were in hand on the date of termination.

13. ARBITRATION

All disputes arising out of or relating to this agreement or to any breach of this agreement shall be settled in the following manner :

13.1 The parties shall discuss the dispute or difference between them and shall endeavour to arrive at an amicable settlement.

13.2 If the dispute or difference cannot be settled amicably, the dispute shall be finally settled under the provisions of the arbitration legislation of Zimbabwe. If the parties cannot agree as to the person who is to be appointed as arbitrator, the arbitrator shall be such person as may be appointed by the President for the time being of the Zimbabwe Institution of Engineers on the application of either party.

13. ARBITRATION contd

13.2 The arbitrator shall apply the law of Zimbabwe.

SIGNED by SES at on the day
of 199

AS WITNESSES

SES S.p.A ROMA

- 1.
- 2.

DIRECTOR

SIGNED by CENG at on the day
of 1990

AS WITNESSES

COCHRANE ENGINEERING (PVT)LTD

- 1.
- 2.

DIRECTOR

8 COST ESTIMATE

The following estimate has been prepared based on the SES generator and incorporating the proposed modifications, including the new gas cleaning equipment designed by Cochrane Engineering (Pvt) Ltd. The drawings from SES were received and details of the generator internals have been established.

The prices quoted are all ex Works and include for 10% sales tax for Zimbabwe gasifiers. Units manufactured in Zimbabwe for export are not subject to sales tax.

For conversion of these prices and for foreign exchange calculation to US dollars we have used the rate ruling at 19 November 1991, namely

$$0,1998 \text{ US\$} = 1,00 \text{ Z\$}$$

These prices are subject to escalation.

	<u>Item of Equipment</u>	<u>Price Z\$ Sales tax included</u>	<u>Foreign currency required</u>
8.1	Generator Unit complete	180 500	18 000
8.2	Gas cleaning equipment	69 500	1 500
8.3	Diesel Engine (conversion estimated)	125 000	70 000

8.4	Generator 44 kW capacity complete with control panel	45 000	6 000
8.5	Fees, royalty agreement Generator only maximum 5% (UNIDO to confirm)	9 025	9 025
	Totals	<u>Z\$ 429 020</u>	<u>Z\$ 104 525</u>

9 GENERAL COMMENT

9.1 Workshop facilities

The modified gasification equipment proposed could be manufactured by any medium sized engineering company with metal cutting, rolling, welding and machine shop facilities. A stress relieving furnace is desirable, for post-welding heat treatment of the equipment prior to assembly.

9.2 Production runs

Following further field testing of a modified plant and incorporating any modifications found necessary, batch production runs could commence. In order that the best possible price could be offered and to make the manufacture commercially viable a minimum order of five plants should be considered.

9.3 As the technical specifications of the cylinder head and piston modifications were not forthcoming from SES we have been unable to estimate the cost of modifying suitable engines, other than to confirm that the work can be undertaken by most engine overhaul shops or appointed agents.

Back-up spares are essential, and the selection of an engine which is in regular use for a given area is important as field servicing is a requirement.

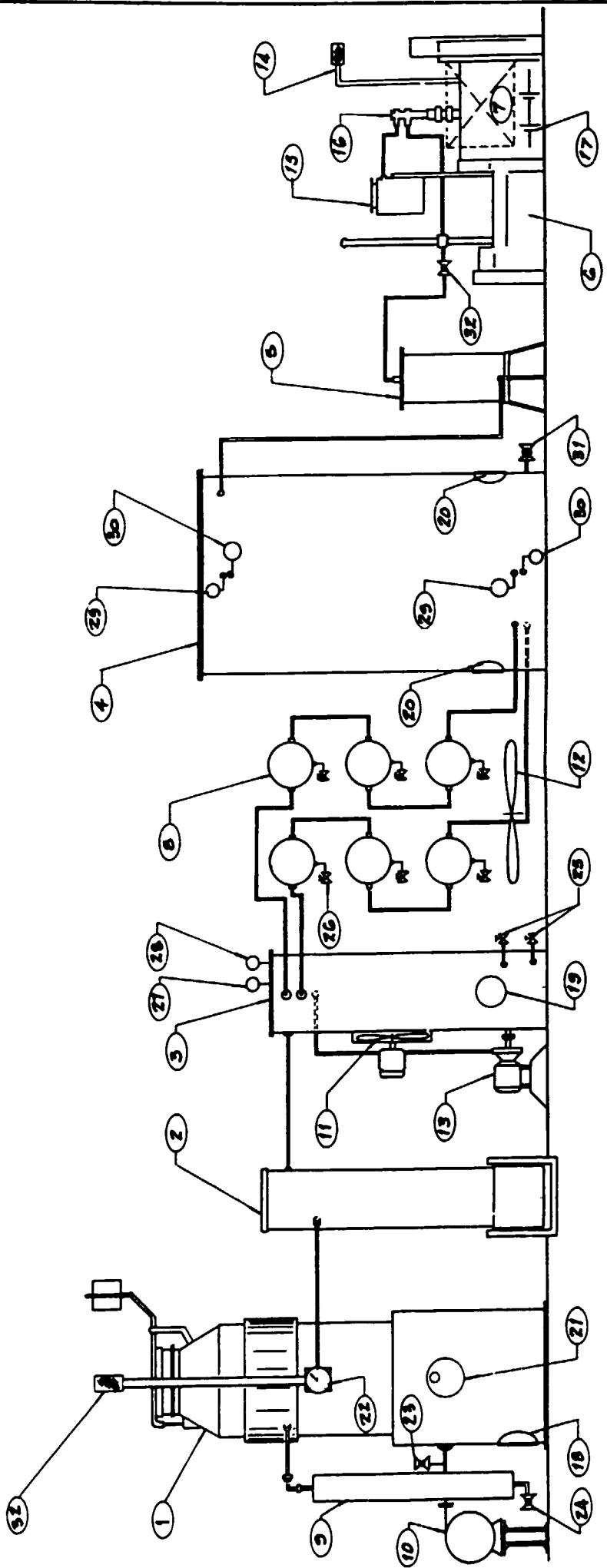
9.4 The availability of filter material has to be established in the area in which the plants are intended to operate as replacement of filter materials must take place at the established intervals.

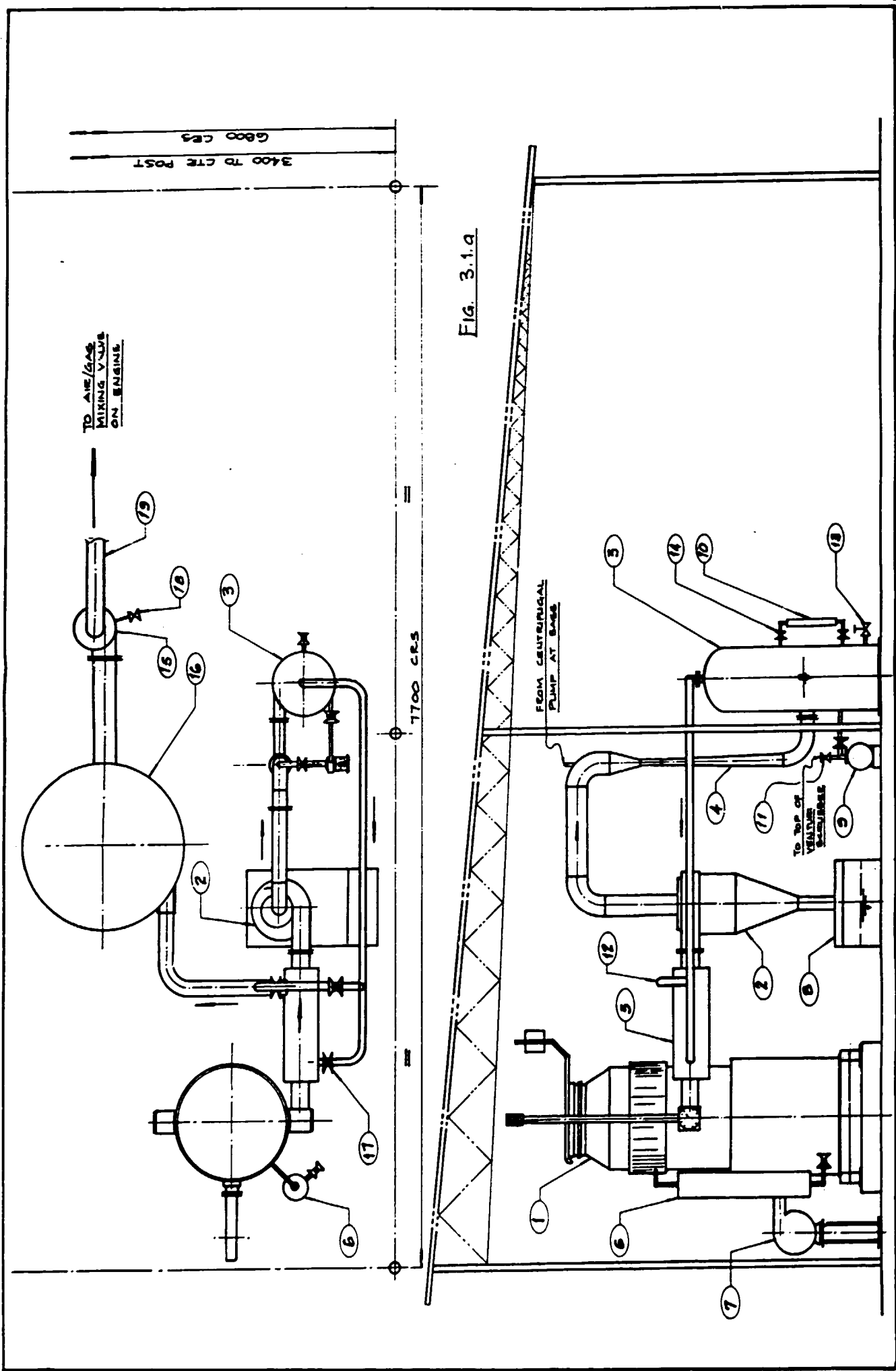
33	
32	CONTROL VALVE
31	CONDENSATE DRAIN VALVE
30	PRESSURE GAUGE
29	TEMPERATURE GAUGE
28	PRESSURE GAUGE
27	THERMOMETER
26	FILTER DRAIN VALVES - 6 OFF
25	PRESSURE DRAIN VALVES
24	CONDENSATE DRAIN VALVE
23	AIR INLET VALVE
22	PRESSURE GAUGE
21	INSPECTION DOOR AND GLASS
20	SAWDUST REMOVAL DOORS
19	INSPECTION DOOR
18	ASH REMOVAL DOOR
17	BATTERY CELLS - 2 OFF x 12V Ea.
16	MIXING VALVE
15	AIR FILTER
14	EXHAUST
13	COOLING UNIT PUMP
12	DISK-TYPE FILTER FAN
11	COOLING UNIT FAN
10	AIR BLAST FAN
9	CONDENSER
8	DISK-TYPE FILTERS - 6-OFF MOUNTED 3 ROWS, 2 COLUMNS
7	CONTROL PANEL
6	ENGINE (TESSARI)
5	SAFETY FILTER
4	FINAL FILTER
3	COOLING UNIT
2	MECHANICAL FILTERING UNIT - 2-OFF
1	REACTOR
PRY NO	DESCRIPTION

FIG 2.1.1.b.

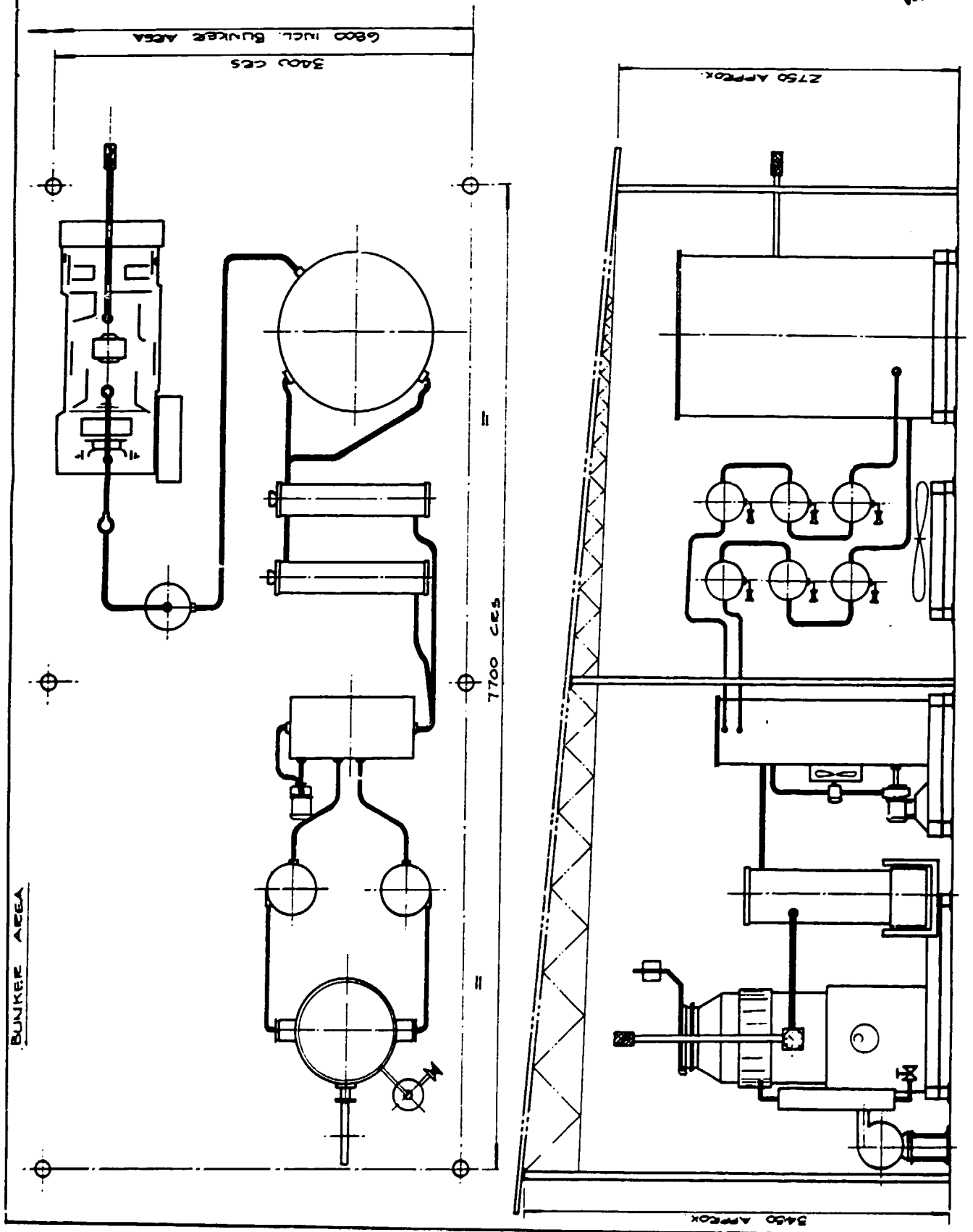
SES MODEL GE 40 GASIFIER

Fig 2.1.1.d.

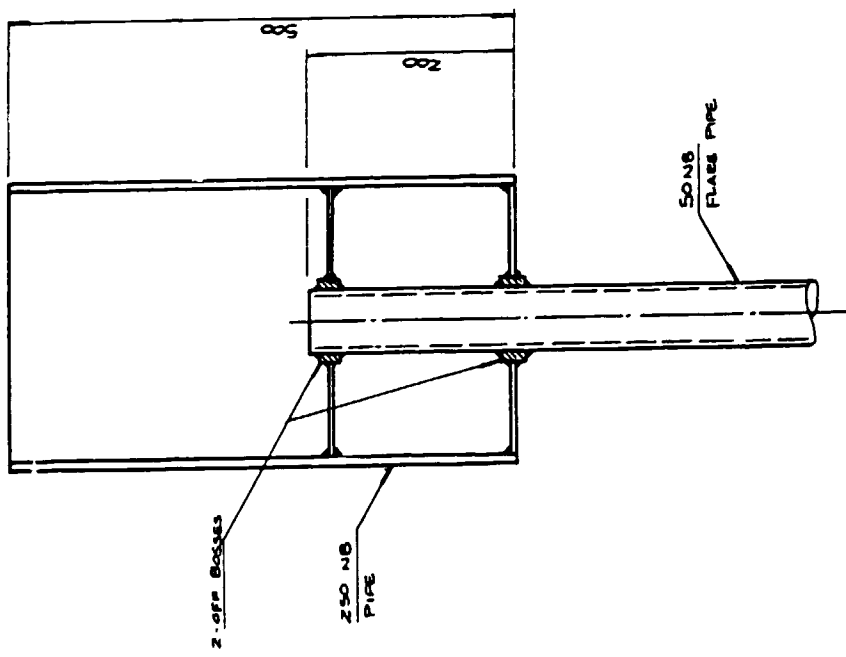




SITE LAYOUT
FIG 3.2.0

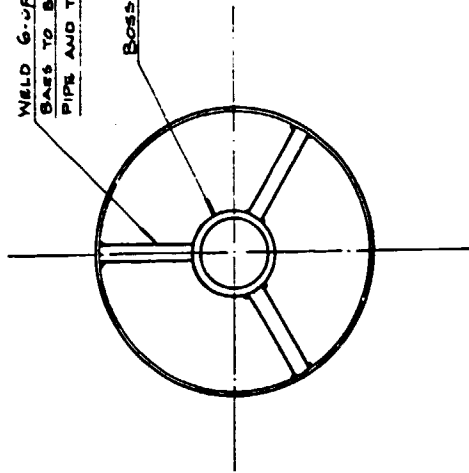


A



WELD 6-OFF FLAY
BASE TO BOTH 250NB
PIPE AND THE BOSSSES

BOSS

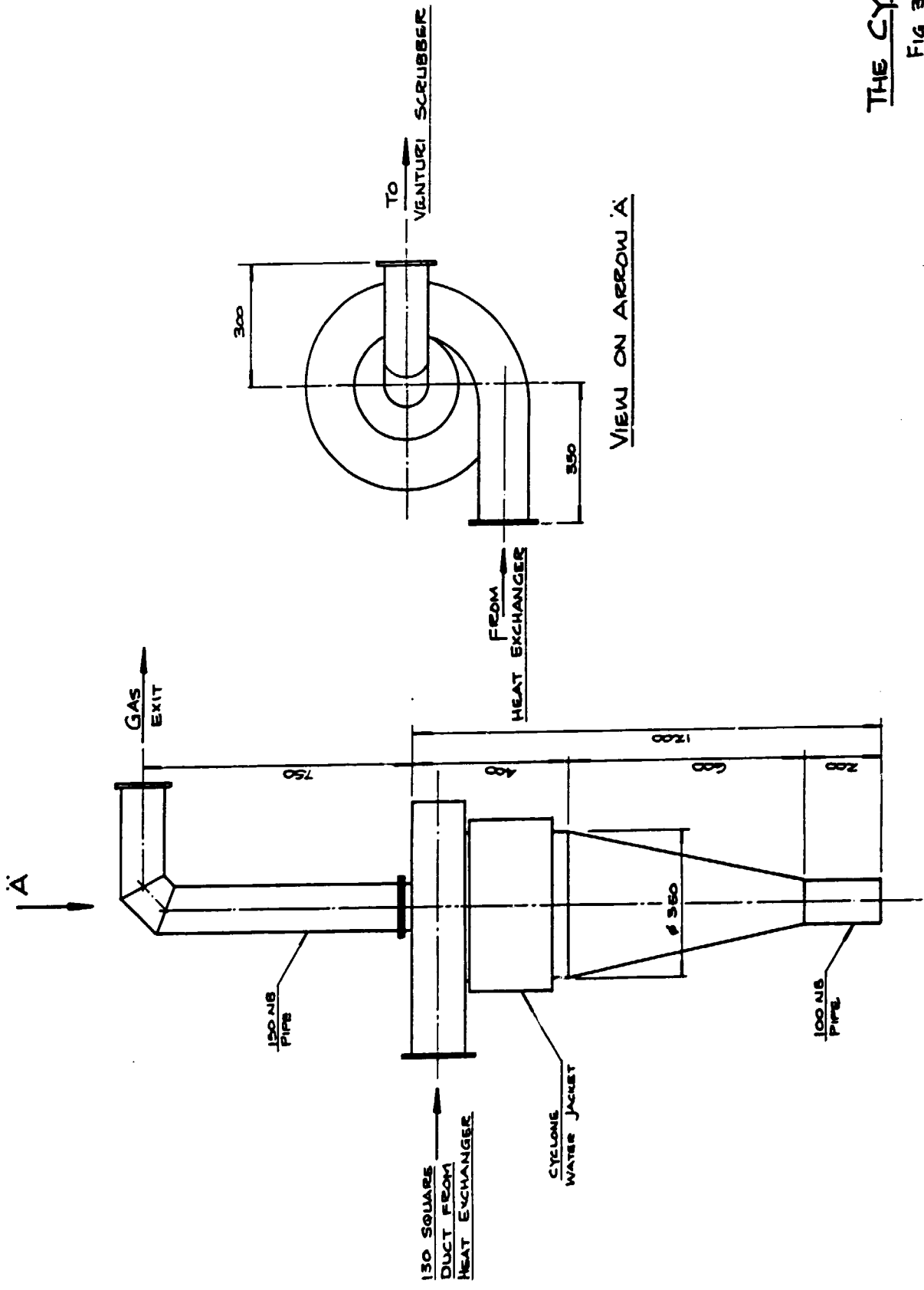


VIEW ON ARROW A

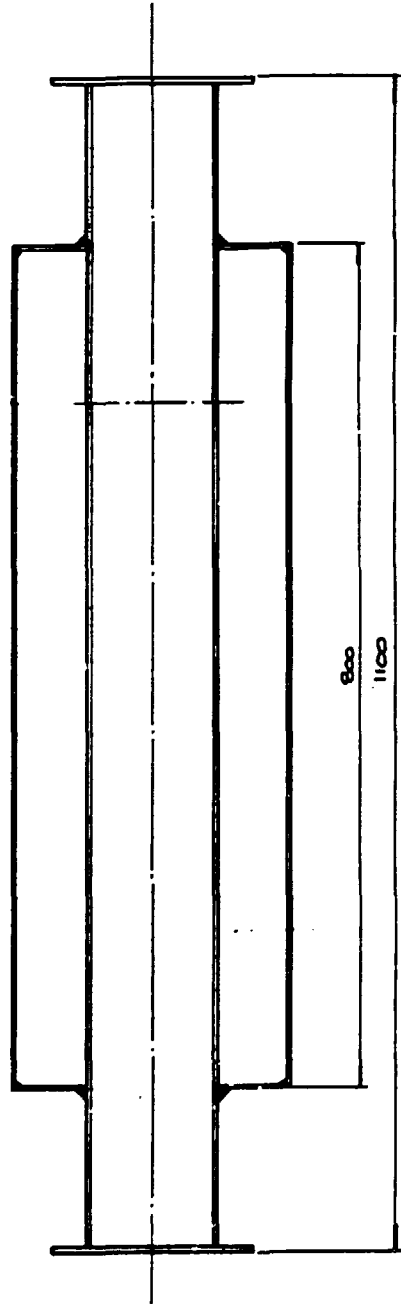
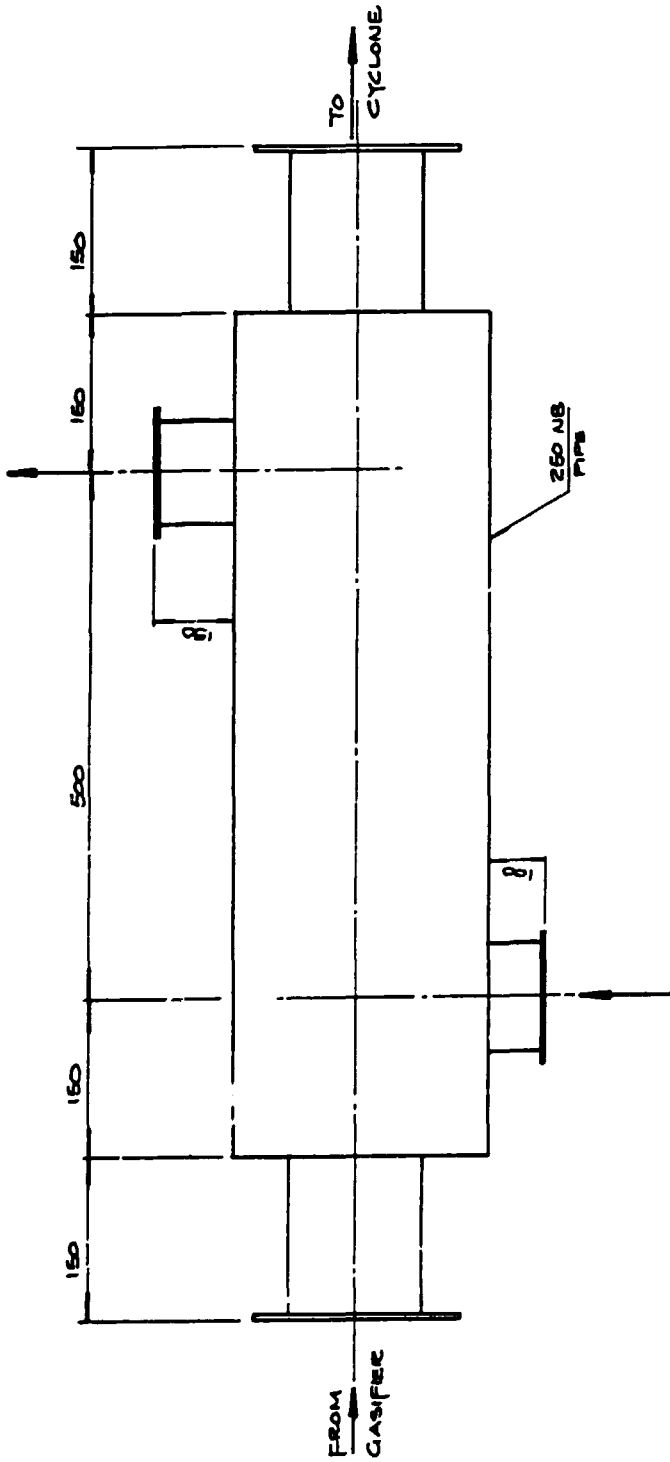
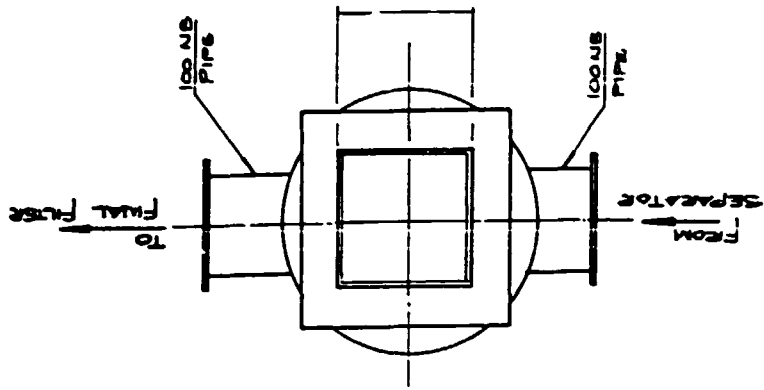
SECTION THROUGH FLARE PIPE END

THE FLARE
FIG 3.2.1.9

THE CYCLONE
FIG 3.2.2.a

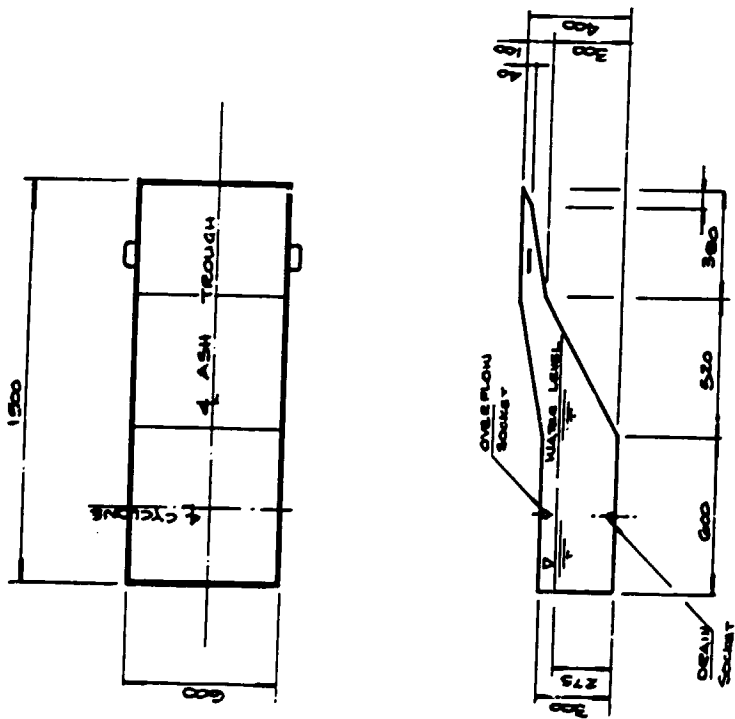


VIEW ON ARROW 'A'

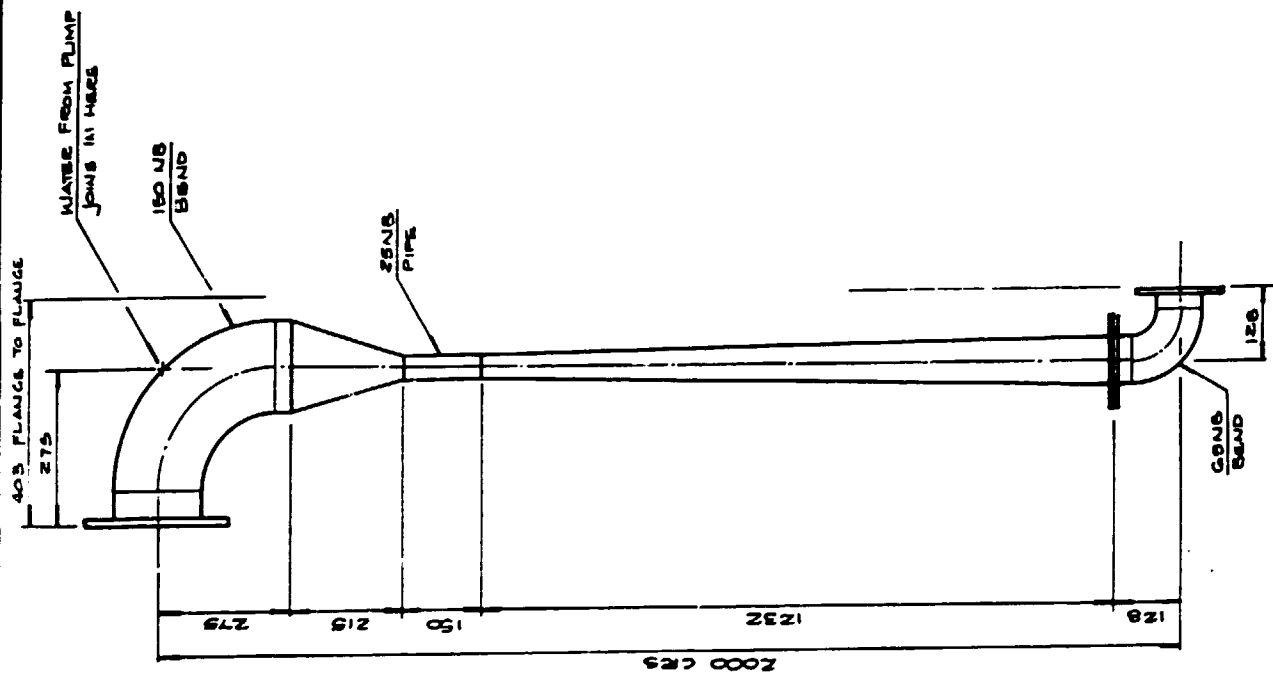


THE HEAT EXCHANGER

FIG 3.2.2.b

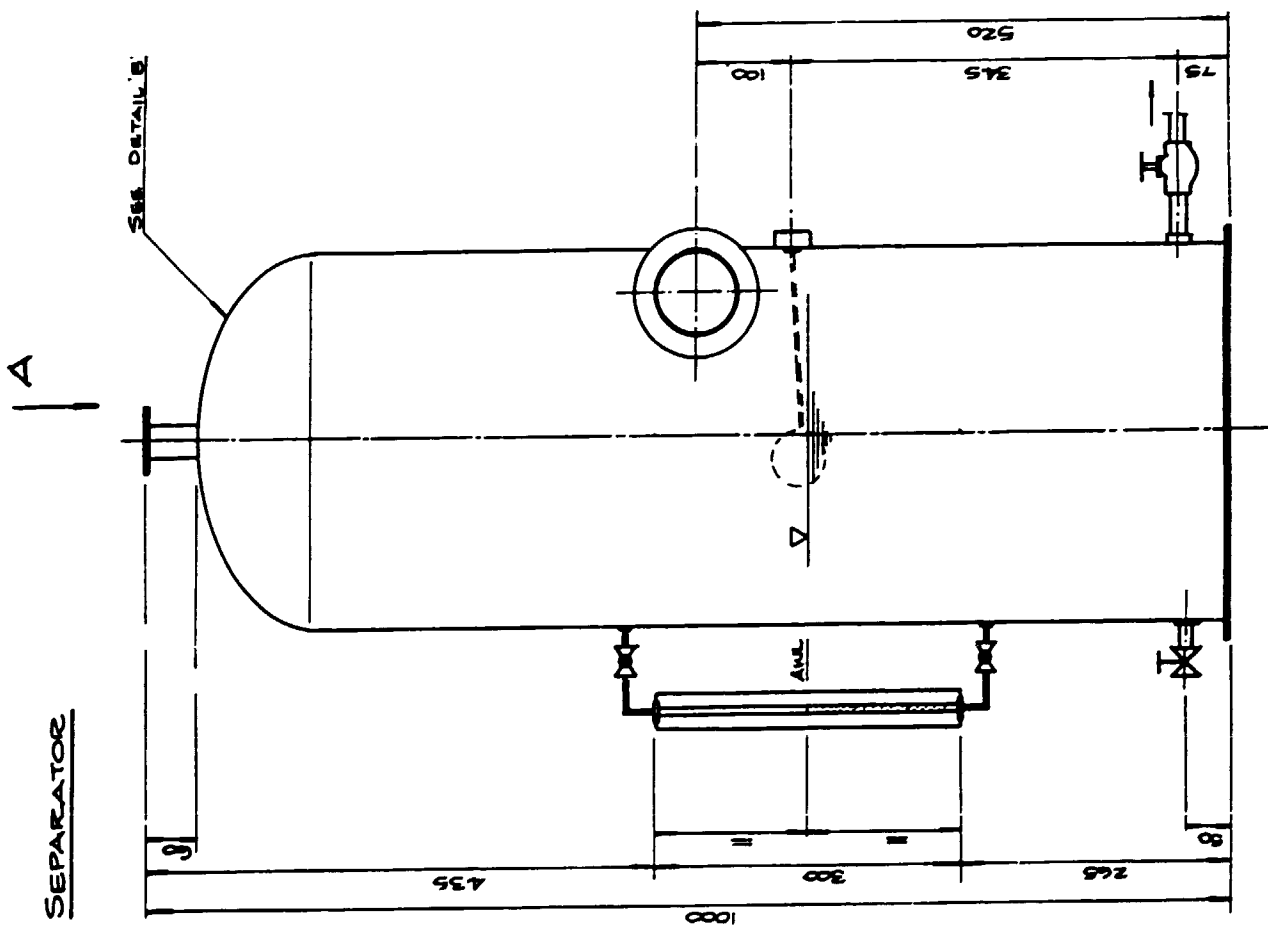


THE CYCLONE ASH TROUGH
FIG 3.2.2.c



VENTURI SCRUBBER (SCALE 1:10) FIG 3.2.4.9.

SEPARATOR



SEE DETAIL 'E'

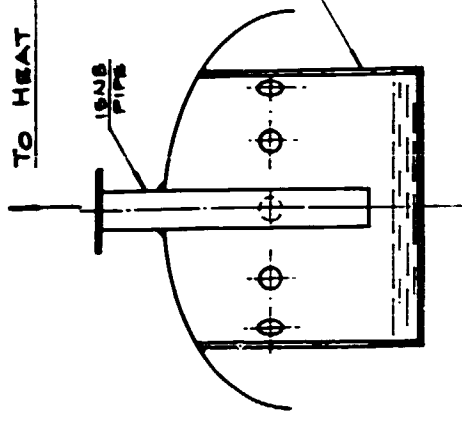
A

TO HEAT EXCHANGER

LONG PIPE

SHORT PIPE

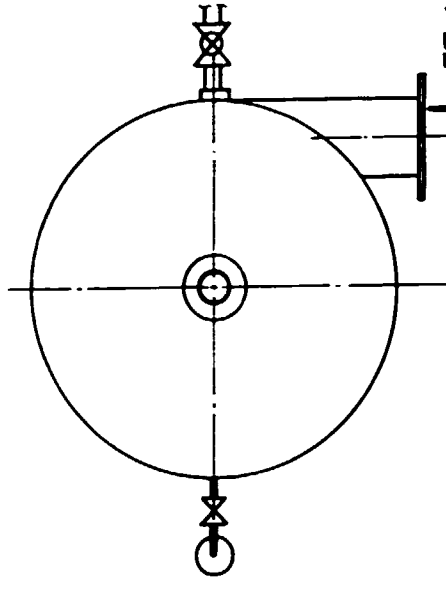
DETAIL 'B'



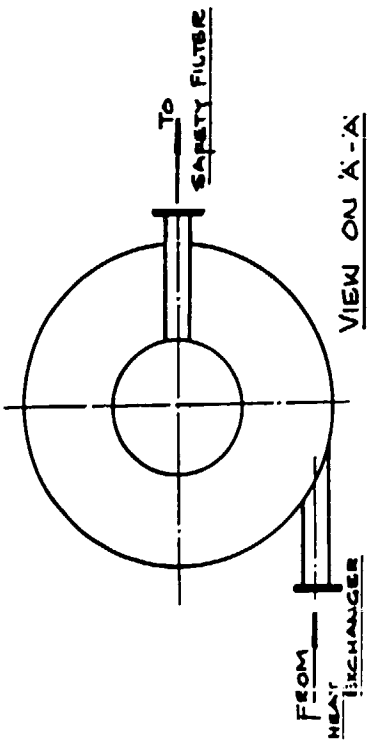
TO CENTRIFUGAL PUMP

FROM VENTURI

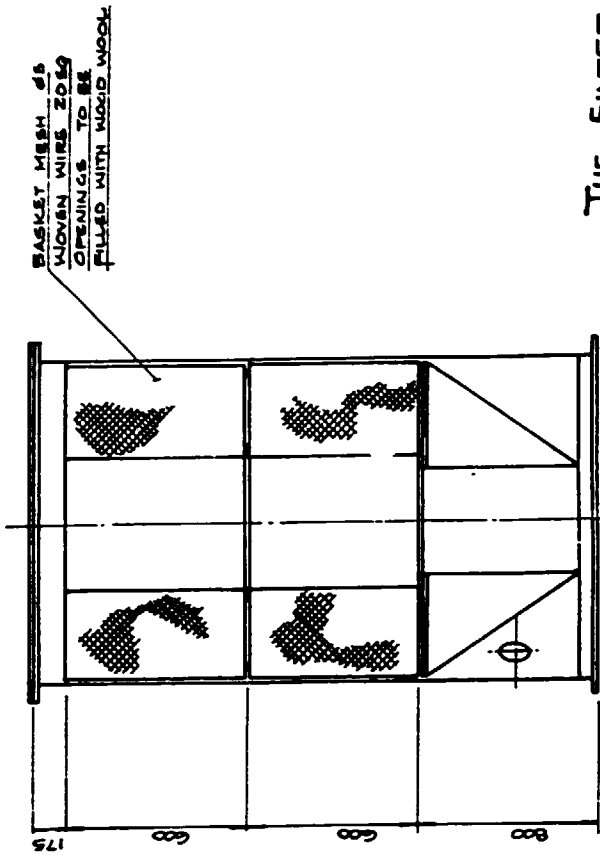
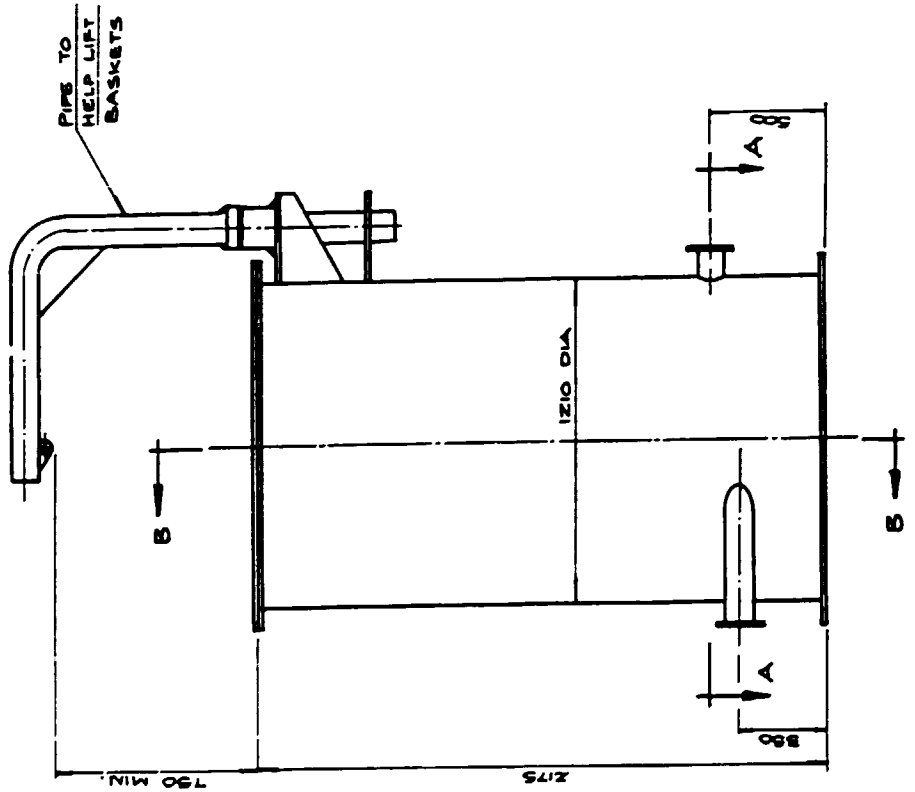
VIEW ON ARROW 'A'



THE SEPARATOR FIG 3.2.5.9

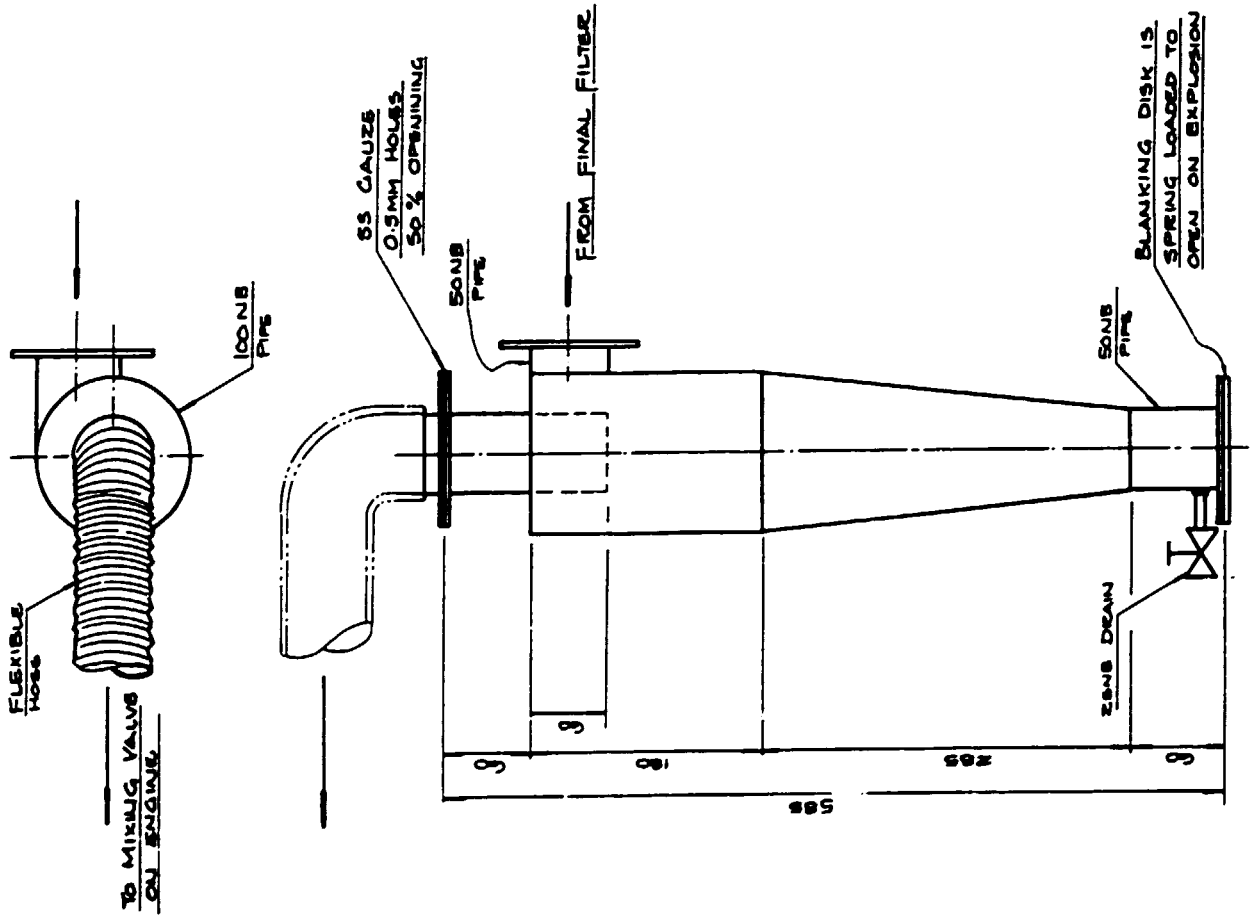


VIEW ON 'A-A'



VIEW ON 'B-B'

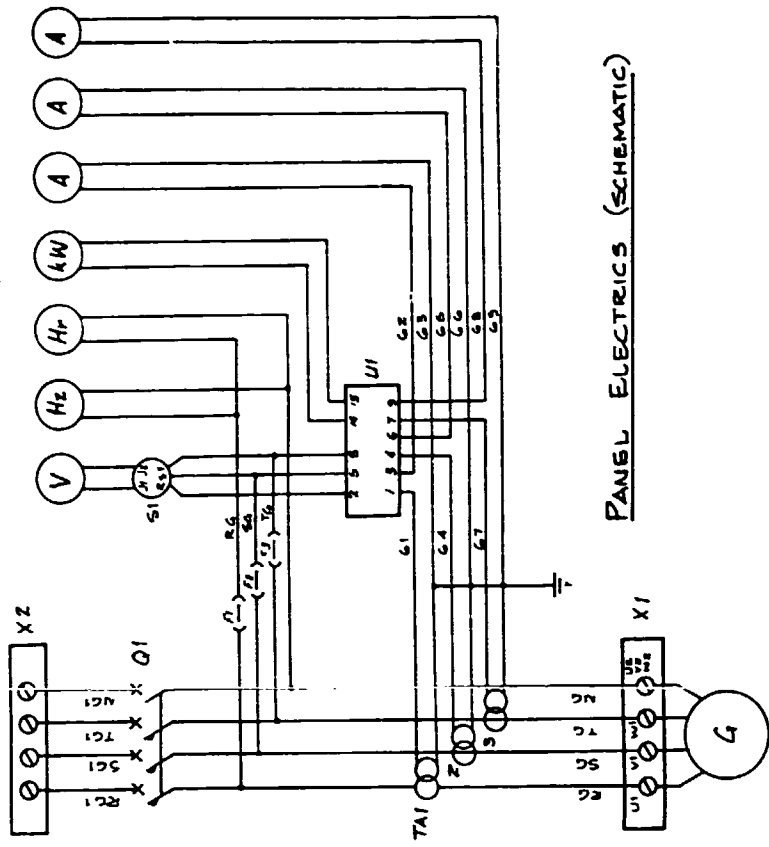
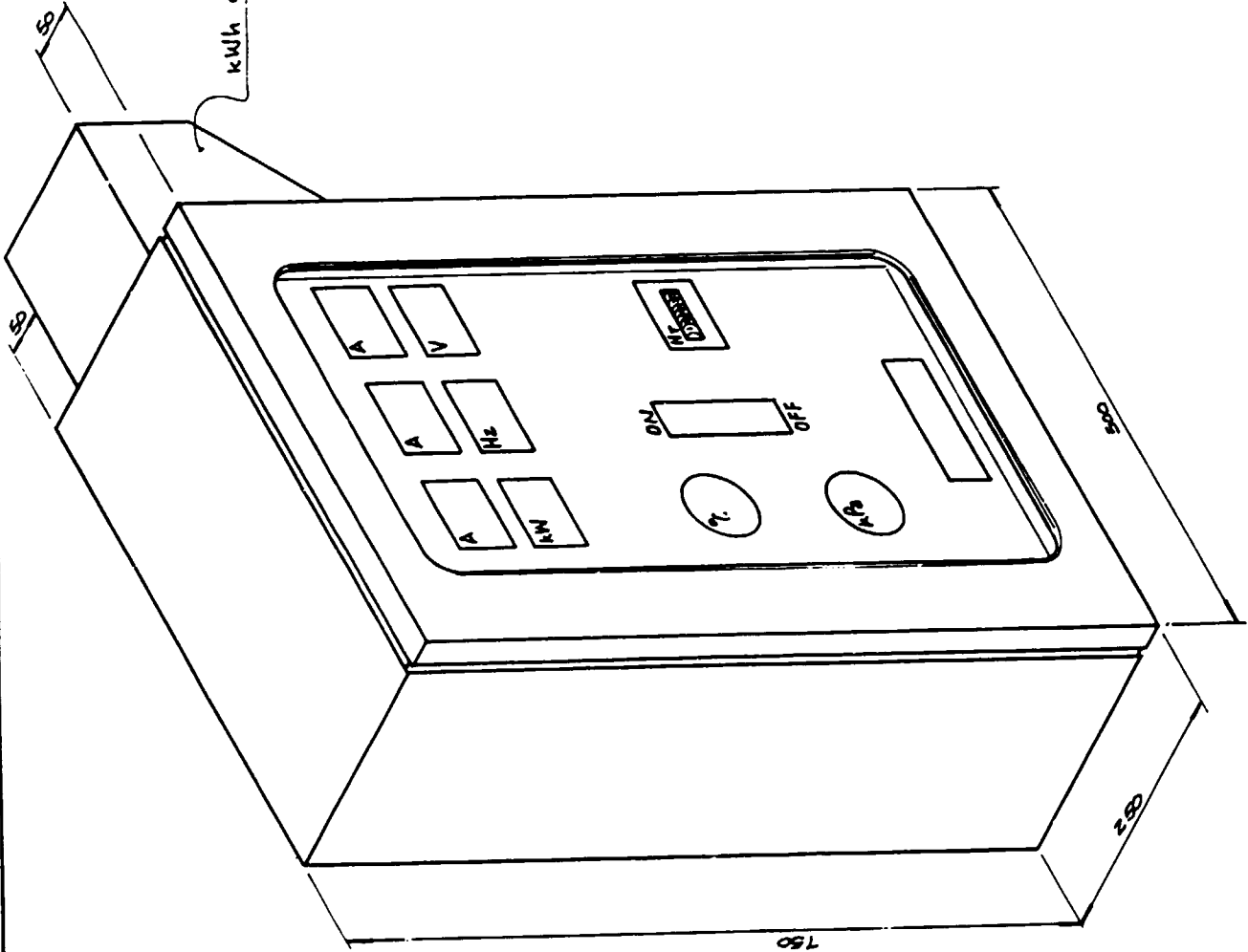
THE FILTER
FIG 3.2.G.a



SAFETY FILTER (SCALE 1:4) FIG. 3.2.7.9

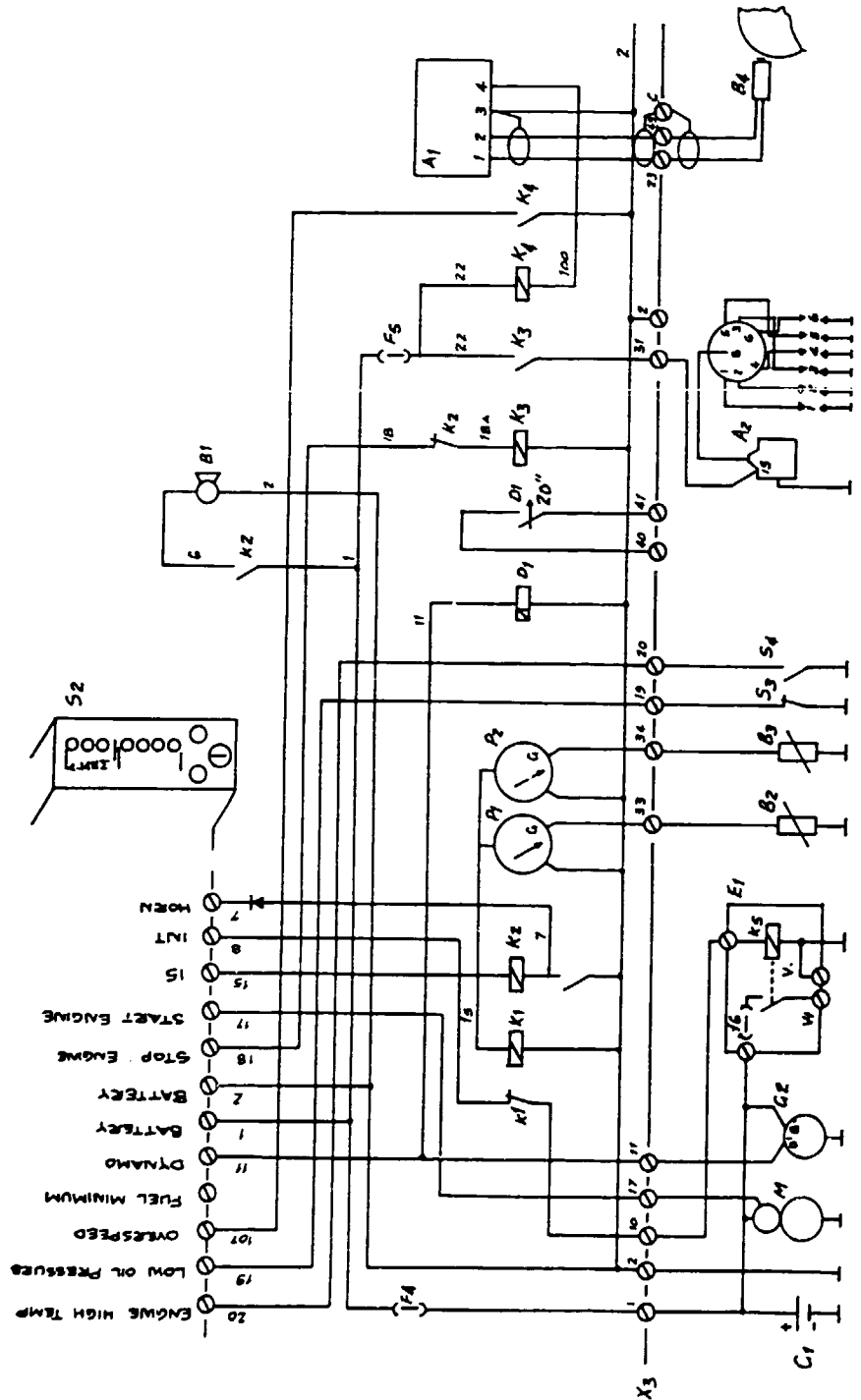
TYPE : E43 B36
 CLASS : Z-O 856689
 A : 3x40-100
 V : 3x280/400
 RVS : kWh 50
 3PH 4W 50Hz

kWh counter



PANEL ELECTRICS (SCHEMATIC)

CONTROL PANEL (SCALE 1:5)
FIG G.1.9.



COMPLEX ELECTRICS (SCHEMATIC)
 FIG G.1.b

GENERATORS

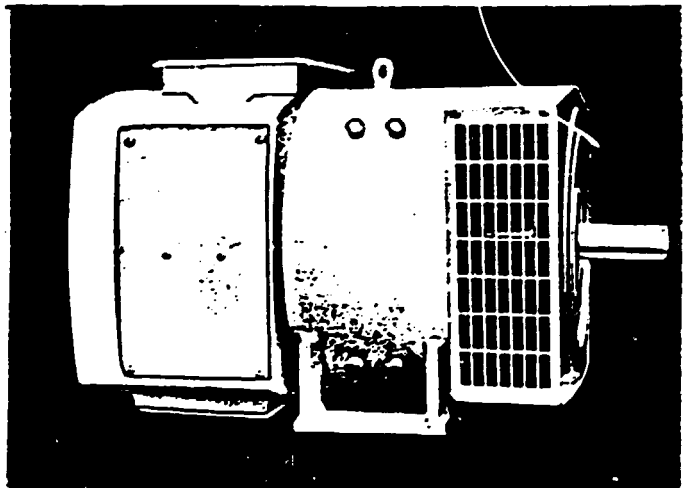
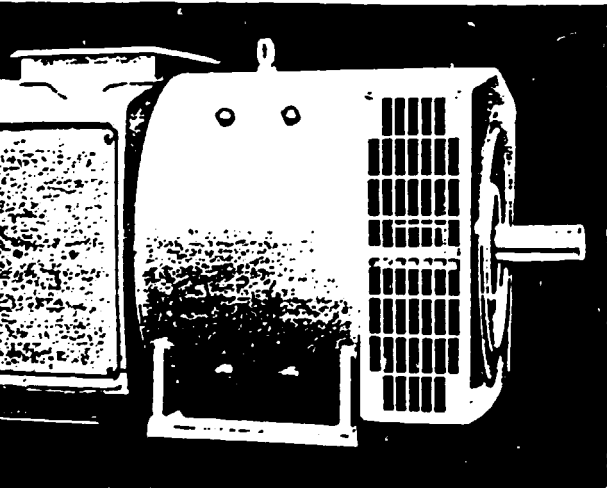
HAWKER

SIDDELEY

**SOUTH WALES
ELECTRIC**

SOUTH WALES ELECTRIC (PVT.) LTD.
P.O. Box 3095, Harare
Zimbabwe
Telephone: 62671 Telex 4218 SWE ZW
Telegraphic Address: "Electric" Harare.

Rotating armature



CRS SERIES

