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In-Plant Training Workshop on the Production of Refractories

Pilsen, Czechoslovakia

11-28 June 1974

DEVELOPMENT OF REFRACTORY KILNS [1]

K. Prabhu *

* Swindell-Dressler Company, Pittsburgh, USA.

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Pilsen (Checoslovaquia)
11 - 28 junio 1974

DESARROLLO DE HORNOS PARA PRODUCTOS REFRACTARIOS[1/]

K. Prabhu*

RESUMEN

En la industria de los productos refractarios se utilizan hornos de las tres grandes categorías, es decir, hornos de funcionamiento intermitente, semicontinuo y continuo, pero los de mayor uso en la actualidad son los hornos de túnel, los hornos de campana y los hornos periódicos.

La elección del combustible para la cocción depende de varios factores; a fin de facilitar la evaluación de las posibilidades, se incluye un capítulo con datos sobre los principales tipos de combustibles: gas natural, petróleo, propano, gas de gasógeno y carbón o coque. Estos datos se refieren a la disponibilidad, el poder calorífico, el tipo de quemador necesario, etc.

La cocción de productos refractarios comprende las siguientes etapas: recalentar los productos hasta alcanzar casi la temperatura de maduración, someter a los productos a la temperatura máxima deseada, manteniendo esa temperatura por un período determinado, y enfriar los productos hasta alcanzar casi la temperatura ambiente. El ciclo de cocción depende del tipo de horno (siendo considerablemente más corto en un horno de túnel que en un horno periódico), la naturaleza del producto y la naturaleza del combustible.

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* Swindell-Dressler Company, Pittsburgh (EE.UU.).

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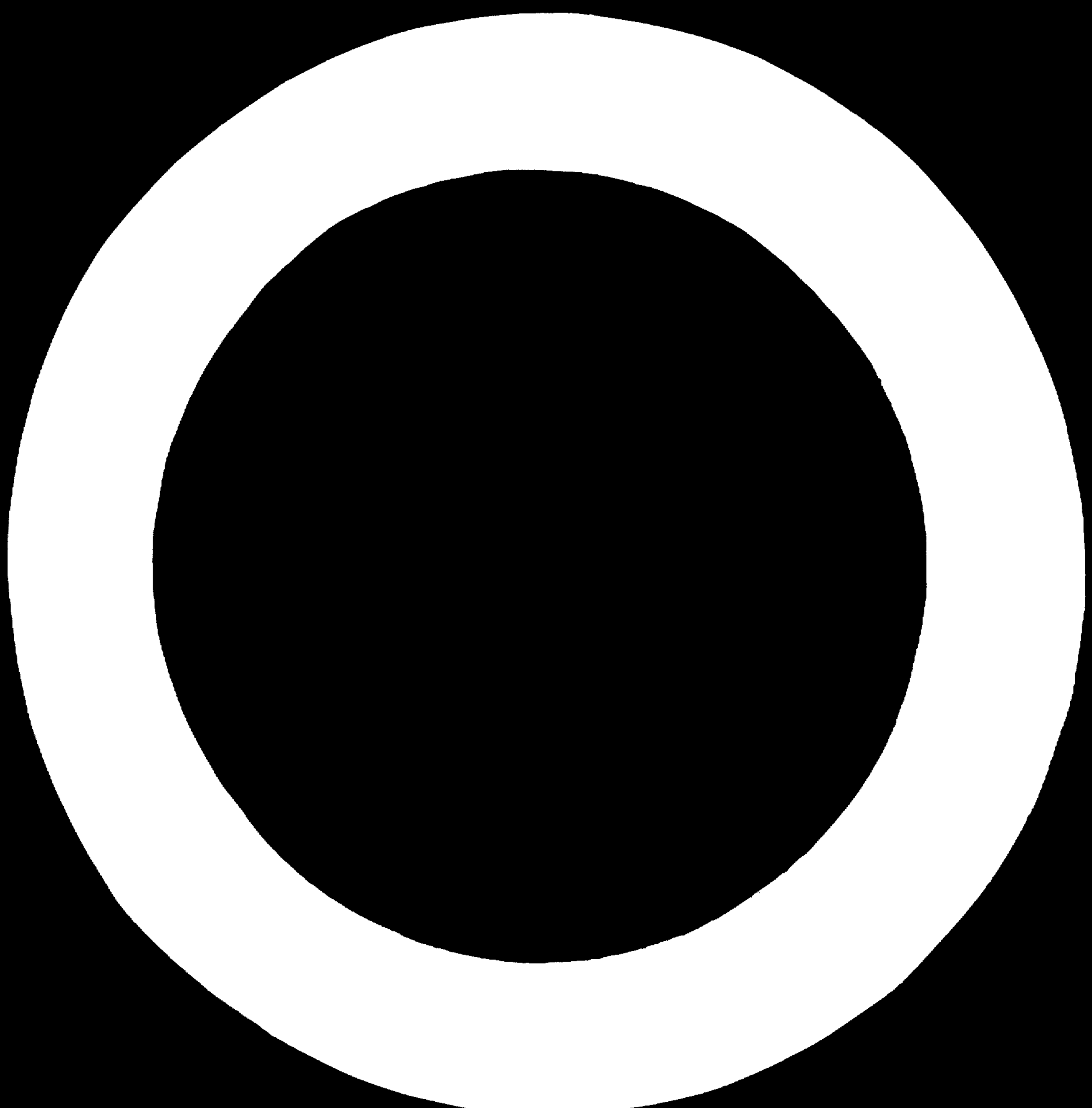

En el capítulo principal de la monografía se describen los tipos de hornos de uso más común para la cocción de productos refractarios. Respecto de cada tipo de horno, se proporcionan detalles sobre su construcción, así como información sobre los tipos de quemadores que requieren, los ciclos normales de cocción y otros aspectos pertinentes, y se enumeran claramente las ventajas de cada tipo de horno. Se llega a la conclusión de que el de túnel es el más económico para la cocción de productos refractarios, en vista de que consume relativamente poco combustible.

En el capítulo final, se resume la información sobre los tipos de hornos utilizados, la temperatura y el ciclo de cocción y el consumo de combustible, basándose en clasificaciones de productos.

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DEVELOPMENT OF REFRACTORY KILNS 1/

K. Prabhu *

SUMMARY

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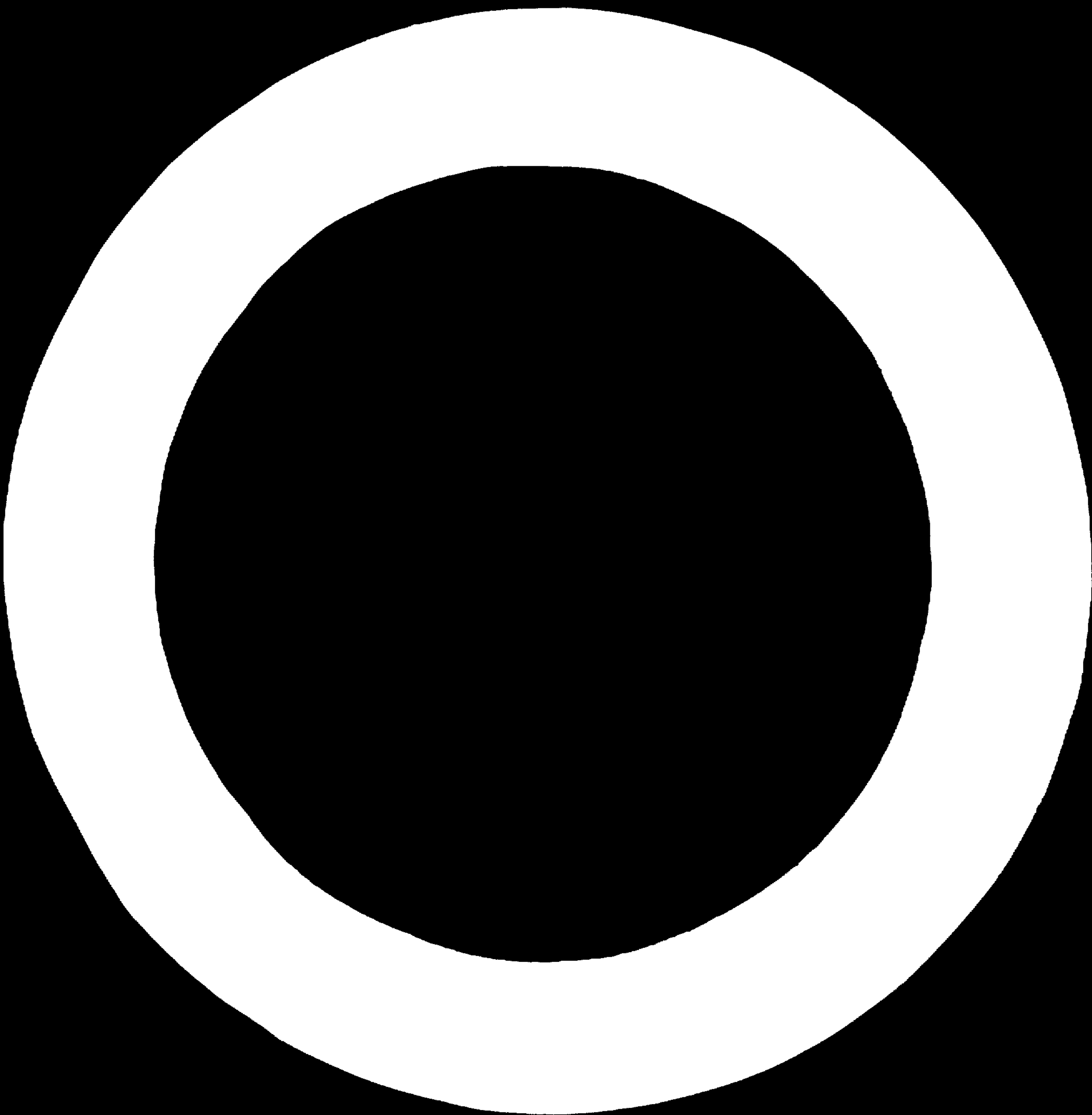
Kilns used in the refractory industry are of all three broad categories, that is intermittent kilns, semi-continuous kilns and continuous kilns, but the most commonly used today are tunnel kilns, shuttle kilns and periodic kilns.

The choice of fuel for the firing depends on a number of factors and in order to facilitate the evaluation of the possibilities, a chapter is devoted to the presentation of data for the main types of fuel: natural gas, oil, propane, producer gas and coal or coke. These data include availability, calorific value, burner arrangements, etc.

Firing of refractories comprises of the following stages, pre-heating of the products almost up to the maturing temperature, bringing the product to the desired maximum temperature and maintaining it at this temperature for a specified period and cooling of the product until the temperature drops almost to the ambient temperature. The firing cycle depends on the type of the kiln (being considerably shorter in a tunnel kiln than in a periodic kiln), the nature of the product and the nature of the fuel.

The major chapter of the paper describes the most commonly used types of kilns for firing of refractories. For each type constructional details are provided as well as information on burner arrangements, normal firing cycles and other relevant aspects and the advantages of each kiln type are clearly enumerated. It is concluded that the tunnel kiln is the most economical method of firing refractories in view of its relatively low fuel consumption.

In a final chapter the information on type of kilns used, firing temperature, firing cycle and fuel consumption is summarised based on product classifications.



CONTENTS

INTRODUCTION

Whereas, drying of ceramic products can be done, if need be, in the open by natural air circulation under ambient temperature conditions, it is essential to have an enclosed structure for the firing of these products with the application of heat -- these structures are known as kilns.

Kilns of some sort or the other are known to have existed thousands of years ago; these were generally the updraft type having a perforated floor and a wall, with a make shift arrangement for the roof. However, some of the early Chinese kilns consisted of a series of chambers having a permanent type of roof. Surprisingly, these kilns were similar in principle to the chamber kilns in operation today and used a high degree of recuperative principle as the fire advanced from one chamber to another.

Kilns used in the Refractory Industry are more specialised than those used in the allied high volume ceramic industry like the Heavy Clay Industry and the White Wares Industry. The temperature of firing is generally higher and the atmosphere control more precise; today some of the kilns in the basic refractory industry are fired to a temperature as high as 3400°F. (1870°C.) with an atmosphere control bordering towards reducing atmosphere, but not totally reducing. In the last decade considerable advance has been made in this direction.

INTRODUCTION - Continued

Refractories can be broadly classified into the following three (3) categories:

(a) Acid Refractories - Like silica bricks.

(b) Basic Refractories- Magnesite, Chrome, Chrome-Magnesite combination and Dolomite type refractories.

(c) Neutral and other special refractories.

(i) Mullite.

(ii) Fire clay and high alumina (even though these are not strictly neutral, these may be classified in this group). These include low heat duty all the way up to super duty type of refractories, high aluminas as well as semi-silica.

(iii) Special refractories, graphite, silicon carbide and fused cast refractories.

Refractories are further classified based on their physical forms. For example,

(a) Standards.

(b) Shapes.

In the former category bricks of certain definite dimensions and relatively simple design which are usually produced in mass quantity. These are generally 9" x 4" x 2 1/2" and 9" x 4" x 3" straights and the corresponding series of archs, wedges, keys, etc. In the metric system the dimensions are 230 mm x 115 mm x 65 mm and 230 mm x 115 mm x 76 mm series.

KILNS

Kilns used in the Refractory Industry are of all three (3) broad categories, that is:

(a) Intermittent Kilns - Here the green bricks or shapes are set, fired according to a definite time-temperature schedule to the desired finishing temperature, cooled and then unloaded. The process is then repeated with a fresh charge of green bricks.

(b) Semi-Continuous Kilns - These are generally a group of intermittent kilns or chambers built together with a common structure and arranged in a way that the gases pass from one chamber to another. Here the first chamber is fired the same way as the periodic kiln, however, the kiln gases (products of combustion or PC gases) instead of escaping through the stack or chimney pass through the second and subsequent chambers. By the time the first chamber has achieved the maturing temperature, the second chamber is at a fairly high temperature. The process is repeated until the last chamber is fired.

(c) Continuous Kilns - These are kilns where the ware is being fired continuously, green ware being loaded in one part of the kiln and fired ware being withdrawn from another part. These are further classified into two (2) main types:

KILNS - Continued

(c) - Continued -

(i) The moving ware or car tunnel type known as tunnel kilns.

(ii) Moving fire or annular type; for example, chamber kilns.

Even though refractories are fired in all of the above type of kilns, the most commonly used today are:

(a) Tunnel Kilns - These are the most economical type of kilns and lend themselves to precise control and distribution of heat throughout the load.

(b) Shuttle Kilns - These are car bottom type of periodic kilns and are used where the volume of production is not high enough for a tunnel kiln and where the products are so diversified (both size as well as product mix) that the firing treatment has to be altered very frequently.

(c) There are several old operations throughout the world where conventional downdraft type of periodic kilns as well as chamber kilns are being used. Round (sometimes rectangular) periodic kilns are quite common in the old

KILNS - Continued

(c) - Continued -

refractory operations (these are particularly useful where the sizes are very varied and need slow and long treatment). However, these are not very economical type of kilns as the fuel consumption is very high.

FUELS

The following fuels are used in various parts of the world for firing of refractories:

(a) Natural Gas.
(b) Oil.
(c) Propane.
(d) Producer Gas or Town Gas.
(e) Coal or Coke.

The choice of the fuel is dependent upon:

(i) Availability and cost per unit of heat and/or output.
(ii) Capital as well as maintenance cost of the equipment required to use the fuel.
(iii) Labor required to operate the equipment.
(iv) Whether the refractory operation is an existing operation or whether it is a brand new operation.

FUELS - Continued

A. Natural Gas

This is a mixture of several paraffin hydro carbons along with nitrogen and oxygen; has a high calorific value ranging from 950 to 1150 BTU's/cu. ft. (8500 - 10,250 K.Cal/cu. m.) and has a low sulphur content. The stoichiometric ratio for perfect combustion is 10 to 1. Unfortunately, this type of fuel is not available in all parts of the world. Where available, this is the best and most economical type of fuel; is very clean and does not require high capital investment for storage. In the United States and several other areas of the world this is the most common type of fuel used in the refractory industry. Temperatures as high as 3400°F. (1870°C.) are fairly easily achieved in well designed tunnel kilns.

There are many types of natural gas burners available today.

(i) The simplest being the raw gas type wherein the raw gas is introduced into the kiln under pressure through specially designed burner; this mixes with the hot air within the kiln causing combustion.

(ii) Pre-mix type of burners wherein the primary air and gas are pre-mixed at some

FUELS - Continued

A. Natural Gas - Continued

(ii) - Continued -

point upstream of the burner port. The burner proper acts as a flame holder maintaining the flame in a desired location.

(iii) Nozzle mix type of burners - Here the gas and the combustion air do not mix until they leave the burner port. A more recent development in this category is the jet type of burner where partial combustion takes place in the burner block itself and creates a jet action accompanied by high velocity. The transfer of heat from the source to the ware could thus be achieved over a longer distance.

B. Oil

Oil is used for achieving high temperatures in the refractory industry. Next to natural gas, oil is the best and most widely used fuel in the world. This fuel is relatively more expensive than natural gas and is not as clean an operation.

FUELS - Continued

B. Oil - Continued -

Oil is available in a number of different grades; the three (3) main categories being:

(i) Light oil - No. 2 oil; gasoline and diesel oil fall in this category. Has a viscosity of 4-5 Engler degrees (120-160 Redwood No. 1 Seconds) at 50°C. (122°F.) and a calorific value of 125,000 - 135,000 BTU's per U.S. gallon (144,000 - 154,000 BTU's per Imperial gallon).

(ii) Medium oil - No. 3 and No. 4 oil. Has a higher viscosity of 8 - 10 Engler degrees (280 - 300 Redwood No. 1 Seconds) at 50°C. (122°F.) and a calorific value of 140,000 BTU's per U.S. gallon (161,000 BTU's per Imperial gallon).

(iii) Heavy oil - Also known as No. 6 or Bunker "C" oil. This is the cheapest oil of the three (3) categories; is very viscous with a viscosity of 50 - 100 Engler degrees (1500 - 3000 Redwood No. 1 Seconds) at 50°C. (122°F.) and a calorific value of 145,000 - 155,000 BTU's per U.S. gallon (168,000 to 180,000 BTU's per Imperial gallon).

A wide variety of burners are available for firing with oil; in principle, they all

FUELS - Continued

B. Oil - Continued -

(iii) - Continued -

atomize (or breakup) the oil into a spray of fine particles and intimately mix them with the combustion air. In the mechanical atomizing type of burners the oil is forced through a fine orifice at high pressures. However, these type of burners become less efficient at low capacities since the orifice has to be very tiny and is liable to be clogged. In the other type, air or steam under high pressure is used to inject the oil into the kiln and at the same time break it into a very fine mist.

While using medium and heavy grade oils, they have to be preheated and kept hot to a specified minimum temperature until they reach the burner. A good continuous type of filter is required and for achieving good results a good oil recirculating system is desirable. Figure No. 1 shows a typical layout for a heavy oil tank farm.

C. Propane (Also Butane)

These are hydro carbons and are easily liquified under

FUELS - Continued

C. Propane (Also Butane) - Continued -

proper conditions of temperature and pressure and transported in that state. They are relatively more expensive and are often used only as a standby fuel.

Propane (or butane) is transported in the liquid state in specially designed trucks or railroad wagons. A typical installation consists of a liquid propane storage tank with the necessary valves, trim and interconnecting piping; a tank/truck unloading system transfers the liquid propane to the storage tank. A pumping station downstream of the storage tank pumps the liquid propane to a vaporizer comprising of a waterbath system and a network of pressure tubes through which the liquid propane is pumped and is vaporized to a gaseous state. This gas is then passed through a nozzle which also inspirates air in regulated proportions and mixes with the propane gas so that the calorific value of the mixture is brought to the desired state which is then stored in a suitable tank under necessary pressure. This pressure tank is in turn connected to the combustion system of the kiln and the switchover from natural gas to this mixture is easily accomplished through a switch.

FUELS - Continued

D. Producer Gas

Producer gas which is used as fuel is, in fact, a semi-water gas which is produced by blowing air and steam through either coal or coke. A gas producer is normally used for generating this type of gas; this comprises of a vertical shaft with an air tight mechanism at the top to supply solid fuel; steam saturated air injection device is located at the bottom of the vertical shaft and a gas drawing off device is located near about the top.

Coal or coke is fed from the top and the air entering at the bottom becomes preheated as it passes through the ash layer. As there is a possibility of melting the ash, thereby, forming clinker and obstructing the working of the Producer, steam is introduced along with the air under regulated conditions depending upon the nature of the ash, thus cooling the ash enough to prevent clinkering. This preheated air/steam then passes through the incandescent Carbon to form Carbon Dioxide in the next immediate adjacent higher zone. This hot Carbon Dioxide and steam reacts with Carbon to form Carbon Monoxide and Hydrogen. At the very top of the fuel layer the hot gases distill the volatile matter out of fresh coal and are drawn off along with the hot gases.

FUELS - Continued

D. Producer Gas - Continued

Since the tar in the distileate is liable to clog the combustion piping, the hot gases are scrubbed and cleaned of this pitch. Any accompanying dust is cleaned with an electro-static precipitator. The calorific value of this cleaned gas is of the order of 125 - 150 BTU's per cu. ft. (1100 to 1500 K. Cal. per cu. m.). The flame temperature of the gas is only 1700°C. (3100°F.) as compared to 2035°C. (3700°F.) for natural gas and 2090°C. (3800°F.) for oil. On account of this, kilns using producer gas cannot attain the temperatures required today to burn basic refractories and certain high alumina type of refractories. Producer gas kilns are usually for lower temperature fired, that is, Cone 16 or even Cone 18/20 burns.

Since this type of fuel is the cheapest gaseous fuel per BTU that can be obtained from solid fuel this is very widely used for providing lower quality refractories and places where natural gas is not available. Producer gas has a distinct advantage over solid fuels on account of the absence of temperature and draft variations, ash deposits on the ware as well as the absence of localised overheating.

FUELS - Continued

D. Producer Gas - Continued

Burners for firing producer gas (especially raw producer gas) are specialized items as there is a tandency for the tar in the gas to clog the burners; the burners are so designed that it will lend itself to cleaning during use.

E. Coal or Coke

In some parts of the world refractories are fired, even today, using coal as a fuel both in the intermittent as well as in the continuous type of kilns. This solid fual is used on account of its very low cost and as the refractories are not sensitive to the impurities in the resulting kiln gases.

Coal is usually burned in furnaces using either a flat or a sloping grate. The air for combustion partly passes through the fuel bed and partly over the bed. In a thirty (30) foot diameter downdraft kiln there are usually about 8 to 10 fire boxes situated all around the kiln for achieving even heat distirubtion. A good grade of bituminous coal having a long flame, low ash content and high ash fusion temperature is normally used. Both manually fed as well as mechanically operated stokers are used for feeding the fuel.

FIRING OF REFRACTORIES

As in the case of most other ceramic products, firing of refractories comprises of the following stages:

(a) Heating the products under specified conditions of time and temperature almost up to the maturing temperature of the ware - This is also known as the preheating period wherein the initial driving of the mechanical water, organic and inorganic reactions, water of crystalization and other associated reactions in the product take place.

(b) Bringing the product to the desired maximum temperature and maintaining the product at this maximum temperature for a specified period; also known as the soaking of the product. This is the main firing period wherein the necessary reactions have already taken place and the volume change has also been completed.

(c) Cooling of the product under defined rates of temperature drop until the product is nearabout the ambient temperature. This period is the cooling period of the product when the glassy phase formed during the maturing of the ware is set without cracking of the same. The total time (a+b+c) is referred to as the cycle for the firing of the product.

The firing temperature and the cycle required to fire the refractories depend upon:

FIRING OF REFRACTORIES - Continued

I. Type of kiln used for firing the product, i.e., the cycle required for firing a Fire Clay Refractory in a downdraft type of periodic kiln is of the order of 5 to 10 days (120 - 240 hours); whereas in a tunnel kiln the cycle ranges from 50 to 75 hours. This is primarily on account of better and more rapid heat distribution achieved in a tunnel kiln as compared to a downdraft kiln. In the latter, considerable time is lost in unloading of the ware, heating up of the massive structure of the kiln as well as achieving uniform heat distribution throughout the load.

II. Nature of the Product - The total cycle, the maximum maturing temperature as well as the soak time for products burned in the same type of kiln is further dependent upon the nature of the refractory; i.e., a Moderate and High Heat Duty Refractory is usually fired to Cone 12 burn in 50 to 75 hours; a bauxite based product is fired to Cone 14 burn and a mullite based product to Cone 23 burn. In case of Silica refractories where crystaleographic phase changes take place accompanied by dimensional changes the cycle in a tunnel kiln is between 120 - 150 hours with a Cone 18 burn and with about 8 - 10 hours of soak. In the case of Basic Bricks

FIRING OF REFRACTORIES - Continued

II. - Continued -

some of the products are fired to a temperature as high as 3400°F. (1870°C.) having a soak of 6 - 8 hours and a cycle varing from 50 hours to 72 hours.

III. Nature of the Fuel - This is true especially in a Downdraft type of periodic kiln when firing with a solid fuel as compared to other fuels. On account of the lack of finer control there is usually a lag while using solid fuels.

TYPE OF KILNS

As explained earlier, The Refractory Industry uses intermittent, semi-continuous as well as continuous types of kilns. The most common being, Tunnel Kilns, Car Bottom Shuttle Kilns as well as Top Hat type of Kilns. Round Downdraft type Beehive Periodic Kilns (sometimes rectangular) are also used where the shapes and sizes are diverse and varied in nature. Description of these kilns is given herebelow with an emphasis on the more recent developments and most commonly used kilns.

A. Intermittent Kilns

(i) Downdraft Type of Kilns -

These kilns are usually round (circular) or sometimes rectangular. The round or

TYPE OF KILNS - Continued

A. Intermittent Kilns - Continued

(i) Downdraft Type of Kilns - Continued

circular kilns are generelly preferred on account of the lower construction and maintenance costs as well as better and more even temperature distribution as compared to that of a rectangular kiln.

The round kiln most commonly used in the industry vary in diameter from 28 ft. to 35 ft.; 30 ft. diameter kilns being the most popular. They usually are 12 ft. from the floor to the springer block (skewback) level reaching about 20 ft. to the apex of the crown which is usually dome shaped. Fireboxes are arranged all around the kiln and are usually 8 or 10 in number. Generally, there are two (2) doors (known as wickets) located diametrically oposite each other. The wall construction is rather massive and is as much as five (5) feet thick. The hot face lining of the kiln is either high heat duty or super duty refractory lining depending upon the temperature to which these are required to be fired. The

TYPE OF KILNS - Continued

A. Intermittent Kilns - Continued

(i) - Continued -

arch is usually constructed of a high fired 12" thick key fire brick covered with suitable insulation. The most common flue arrangement is a radial type of flue; there being a series of openings in the kiln base (floor) leading into radial flues about 2 ft. to 3 ft. deep, 9" to 12" wide which in turn connects to a main central flue leading to the chimney (stack). For both economy and for producing better draft conditions, usually a group of 4 to 5 kilns are connected to a single stack with separate flues connecting to each kiln.

The setting of the ware usually depends upon the size and shape of the product being fired. Where there is a varied range of products, the big blocks are set at the bottom and are usually boxed using fired tiles. The rest of the setting is in a checkerwork pattern forming benches running across the kiln and about 3 - 5 ft. wide. There is a gap of about 6" to 8" between benches. To prevent sticking of bricks to one another fine silica sand is sprinkled on each layer of bricks.

TYPE OF KILNS - Continued

A. Intermittent Kilns - Continued

(1) - Continued -

After every 10 to 12 courses set an edge, a fired brick or tile is flat set and the setting pattern continued extending all the way to within one (1) ft. of the crown and following the contour of the crown (however, in the case of silica bricks it is not set that high to allow for expansion of the brick). Basic brick and other special products which cannot support themselves are usually boxed in fired silica tiles.

The capacity of a 30 ft. diameter kiln is approximately 100,000 equivalents (9" x 4 1/2" x 2 1/2" or 230 mm x 115 mm x 65 mm equivalent).

The cycle for burning fire clay products in this kiln is usually 10 to 12 days (1 to 2 days loading or setting of the ware; 4 to 5 days heating including 1 day soak; 4 days of cooling and 1 to 2 days of unloading). In the case of the silica bricks the cycle is as high as one (1) month.

By using combustion blowers and PC fans, and thereby, accelerating the burning and cooling periods the cycle has been drastically reduced.

TYPE OF KILNS - Continued

A. Intermittent Kilns - Continued

(i) - Continued -

The most commonly used fuel was bituminous type of coal using either manual or mechanical stokers. Subsequently, most of these kilns have been changed to either producer gas, oil or natural gas type of fuel. In the United States these kilns are usually fired with natural gas using plain raw gas type of burners.

(ii) Improved Version of Downdraft Kiln

Over the last few years considerable progress has been made in the design and construction of the kiln with the view to achieve fuel economy and improve temperature and heat distribution throughout the load as well as reduce the firing cycle.

This kiln is shown in Figure No. 2. The side-walls are built on a concrete curb slab. The kiln is lined with a 9" hot face insulating brick covered with a 2" - 3" thick layer of insulating castable or blanket.

Exhaust of the gases is through a series of under-ground longitudinal secondary flues which are

TYPE OF KILNS - Continued

A. Intermittent Kilns - Continued

(ii) - Continued -

connected at either end to the primary flues running underground all around the kiln. The primary flue in turn is connected to a chimney or stack.

For proper balancing of heat in the kiln the secondary flues have a vertical damper at each end and the primary flue has also a vertical damper to control the amount of exhaust from the kiln as well as to maintain the required pressure inside the kiln. With this type of flue arrangement even heat distribution is achieved both from side to side and from top to bottom.

The burners are usually located at the skewback (springer block) level and fire over the top of the load. Using this burner arrangement and combined with the flue system a high pressure top firing principle is achieved which:

(a) Produces enough pressure for exhausting the kiln without using a large stack or F.C. exhaust fan.

TYPE OF KILNS - Continued

A. Intermittent Kilns - Continued

(ii) - Continued

(b) Keeps the crown cool and not overheated; thereby, the escape of heat from the crown is practically negligible.

The cooling of the kiln is accomplished using a small cooling blower situated beside the exhaust stack. The blower forces cool ambient air down the stack and through the flues into the kiln.

This air exits through cooling ports provided in the sidewalls nearabout the burner ports.

The entire firing and cooling could be programmed and thereby, automatically controlled.

This kiln is a considerable improvement over the conventional periodic kilns and has:

(a) Reduced the firing cycle.
(b) Improved fuel efficiency.
(c) Produced better and more uniformly burned product.

TYPE OF KILNS - Continued

A. Intermittent Kilns - Continued

(iii) Shuttle Kilns and Top Hat Kilns

This type of kiln is used normally for firing special shapes and larger size pieces and also where the volume of production is not very great. For larger volumes of production, tunnel kilns are most economical and convenient to use. However, some refractory manufacturer's use shuttle kilns also for large volumes of production mainly on account of the wide variety of product mixes requiring varied heat treatments and in some instances special heat treatment.

In the shuttle kiln (also known as car bottom periodic kiln or trolley hearth kiln) the green ware is placed on top of the kiln cars and the cars are placed inside the kiln. After closing the door (sometimes two (2) doors located on either end of the shuttle kiln) the firing operation is started. A spare set of kiln cars are usually provided for setting of the ware while the kiln is being fired; thereby, the loading and unloading time is practically eliminated from the total cycle.

TYPE OF KILNS - Continued

A. Intermittent Kilns - Continued

(iii) - Continued -

The top hat kiln is very similer to the shuttle kiln in operation except that the entire kiln structure could be raised or lowered usually by synchronized hydraulic cylinders. In some of these kilns the setting base itself is stationery and the kiln structure is moved from one base to another. In others, the setting base is a kiln car (as in the case of the shuttle kiln) and could be moved.

Figures Nos. 3, 4, 5 and 6 show the details of a two (2) car shuttle kiln together with a layout and a typical setting pattern. As these kilns are intermittent in nature and are constantly heated up and cooled down the lining of these kilns is usually a hot face insulating brick backed with suitable quality insulating brick, block and/or blanket. The entire structure is enclosed in a steel shell so that there is a minimum loss of heat.

The arch is also constructed of insulating brick backed with suitable insulation. This can be either a sprung type of arch (figure

TYPE OF KILNS - Continued

A. Intermittent Kilns - Continued

(iii) - Continued -

No. 6) or especially designed flat arch (Figure No. 4) depending upon the width of the kiln and the temperature to which these are subjected to. The flat arch is a specially designed type of arch wherein the bricks are suspended by special alloy hangers and rods.

Shuttle kilns for temperatures as high as 3200°F. (1760°C.) have been designed. For such temperatures either a bubble alumina type of insulating refractory or a mullite bonded light weight alumina refractory is usually used as the hot face lining. This is backed with suitable quality low temperature insulating brick. In the refractory industry these kilns are usually of the downdraft type wherein the products of combustion are exhausted through openings in the kiln car and then through special openings lined with proper quality refractory material in the floor and finally to the stack through a PC exhaust fan controlled by a suitable

TYPE OF KILNS - Continued

A. Intermittent Kilns - Continued

(iii) - Continued -

damper. Burners are located (usually jet or high velocity type) at the four (4) corners of the kiln and at different elevations as shown in Figure No. 3 and Figure No. 4. This system creates a turbulence inside the kiln, thereby, achieving the necessary uniform heat distribution throughout the load before exhausting the gases through the openings. Usually these kilns have a capability of having the entire cycle, both heating and cooling, on an automatic control operation.

Figure No. 5 shows a typical setting pattern and track layout for such a kiln. The double set of unloading tracks are provided for the entre set of kiln cars that are generally used.

Figures No. 7 and No. 8 show a wider and longer shuttle kiln. This is a two (2) car wide shuttle kiln and is eleven (11) cars long. The burner arrangement is somewhat different, in that, these are located on the sides at fixed locations and at various elevations.

TYPE OF KILNS - Continued

A. Intermittent Kilns - Continued

(iii) - Continued -

The burners fire into index spaces (firing lanes provided in the setting pattern) for proper combustion. On account of higher temperature capability the kiln has a sprung arch instead of a conventional flat arch normally used for these types of widths.

Figure No. 9 shows the cross section of a typical top hat kiln. The general wall construction and combustion system is similar to the shuttle kiln. However, the design is such that the kiln structure can be raised or lowered by means of a hydraulic lifting mechanism. These type of kilns have limited dimensions as the hydraulic mechanism becomes very expensive with larger and heavier kilns.

Both the shuttle and top hat kilns are used for firing various types of refractories like fire clays, high alumina refractories, silica bricks

TYPE OF KILNS - Continued

A. Intermittant Kilns - Continued

(iii) - Continued -

including coke oven shapes as well as various basic type of refractories up to a temperature of 3200°F. (1760°C.). The limitation of the top temperature is due to the non-availability of suitable higher temperatura insulating refractory brick.

Usually an external hot air recuperator is used for achieving temperatures beyond 3000°F. (1650°C.) both for achieving fuel economy as well as for faster cycles.

The main advantages in such kilns are:

(a) Flexibility of firing.
(b) Capability of firing wide range of shapes and sizes.
(c) Ability to fire small batches.
(d) Achieving faster firing cycles as compared to a periodic kiln.

However, the disadvantages as compared to a tunnel kiln are:

(a) Higher fuel consumption; at 3200°F. (1760°C.) the fuel consumption in this type of kiln is

TYPE OF KILNS - Continued

A. Intermittent Kilns - Continued

(iii) - Continued -

(a) - Continued

2 1/2 to 3 times that of a tunnel kiln.

(b) Higher maintenance costs on account of the severity of abuse of the kiln structure owing to constant heating and cooling.

(c) Higher initial capital investment for larger volumes of production.

B. Continuous Kilns

(i) Continuous Chamber Kilns

These are a series of chambers with common structure and arranged in a way that the hot gases move from one chamber that is being fired to the next chamber; and thereby, transferring the heat to the ware that is being preheated. The principle is the same in the case of chambers that are being cooled -- here cold air is forced into the coldest chamber that is getting ready for unloading and then passes through the adjoining chambers that are also being cooled. By the time this air reaches

TYPE OF KILNS - Continued

B. Continuous Kilns

(i) - Continued -

the chamber that is being fired the air has already achieved a sufficiently high temperature for combustion and thereby achieved the recuperation.

There are very few chamber kilns for firing refractories in the United States, but in many parts of the world chamber kilns were used extensively before the tunnel kilns came into operation. Most of the chamber kilns have blowers and suction fans which aid in rapid firing, thereby, reducing the cycle. As compared to a periodic kiln, the fuel consumption in a chamber kiln is considerably less. However, the heat distribution through the load is not as good as that of a tunnel kiln.

(ii) Tunnel Kilns

Today tunnel kilns are most widely used in the refractory industry. In fact, most new refractory plants are designed around a tunnel kiln for the major percentage of its production. In some

TYPE OF KILNS - Continued

B. Continuous Kilns - Continued -

(ii) Tunnel Kilns - Continued -

instances, the layout provides for a shuttle kiln for specialized items of production.

Some of the advantages of a tunnel kiln are:

(a) A better and more uniform quality product.

(b) Faster firing cycle on account of rapid penetration of heat.

(c) Best fuel economy not only on account of faster cycle, but also due to maximum recuperation of heat.

(d) Low maintenance cost as most of the kiln structure is under steady temperature conditions. Car decks are the major replaceable items and with proper deck design this too can be minimized considerably.

(e) Ability to achieve repetitive firing treatment over extended periods.

(f) Economical in overall operation. Even though the initial cost is at times high, TYPE OF KILNS - Continued -

3. Continuous Kilns - Continued -

(ii) Tunnel Kilns - Continued -

(f) the actual capital investment per unit of production is in most instances no higher then that of a periodic kiln.

Tunnel kilns usually consist of an elongated tunnel comprised of various zones, that is,

(a) Preheat Zone.

(b) Furnace Zone;

(c) Cooling Zone.

Steady temperature conditions are maintained in different parts of these zones. Green ware set in a definite pattern on top of kiln cars is moved continuously through these kilns by means of a hydraulic pusher and at a pre-determined rate. Thus, the ware is constantly subjected to a defined heat treatment pattern.

Figures No. 10 through No. 15 show the details of typical tunnel kilns showing the longitudinal

TYPE OF KILNS - Continued

B. Continuous Kilns - Continued

(ii) Tunnel Kilns - Continued -

plan, typical cross sections and setting patterns.

Figures No. 10 and No. 11 show the details of a tunnel kiln used for firing high alumina type of fire clay refractories; the low setting height being governed by the nature of the product itself. Figure No. 16 shows the setting pattern of a regular fireclay brick (moderate and high duty refractory) and the setting height shown is approximately 72 inches.

As the kiln is subject to constant temperature conditions in various zones, the hot face lining is a hard refractory brick backed up with suitable quality insulating brick followed by block insulation or blanket. The entire structure is enclosed either in a steel shell or lined with face brick.

The quality of the hot face kiln lining depending upon:

TYPE OF KILNS - Continued

B. Continuous Kilns - Continued -

(ii) Tunnel Kilns - Continued -

(a) The temperature to which the particular zone is subjected.

(b) Nature of the products of disassociation from the ware (known as cookoffs) and its effect on the kiln lining.

Thus, the early part of the preheat zone is usually lined with low heat or moderate heat duty type of refractory followed by super duty refractory in the latter part of this zone. In the United States where the silica refractories are less expensive than the super duty type of refractories the furnace zone in most instances is lined with either silica or super silica type of refractories up to a temperature of approximately 3000°F. - 3100°F. (1650°C. - 1705°C.). In basic brick kilns the lining is mostly a basic refractory.

In kilns where the temperature requirements are as high as 3300°F. - 3500°F. (1805°C. - 1925°C.),

TYPE OF KILNS - Continued

B. Continuous Kilns - Continued -

the furnace zone lining is a specialized refractory like the Fused Cast Alumina.

The refractories used in the cooling zone also follow the same pattern depending upon the temperature to which this zone is subjected to. As the atmosphere is usually clean, reaction of the gases with the lining is of minor importance. The last portion of the cooling zone is usually lined with a moderate heat duty or low heat duty type of refractory.

The hydraulic pusher is located at the start of the kiln (Figure No. 10) or in the vestibule area (Figure No. 12).

The early part of the preheat zone (Figure No. 10) or the entire preheat zone has offtake ports for exhausting the kiln gases from any desired portion of the kiln and thus shape the firing curve. The design provides for exhaust flues in the sidewalls of the kiln which are connected to the exhaust ports mentioned above in the inside wall of the kiln and to the intake side of the exhaust fan and then to the stack throgh suitable sheet metal ductwork.

The heat distribution throughout the load in this

TYPE OF KILNS - Continued

B. Continuous Kilns - Continued -

portion of the kiln is achieved by:

(a) Designing high temperature special alloy recirculating fans in the sprung arch located at convenient positions (Figure No. 10); some of these water cooled fans can be used for temperatures up to 2000°F. (1100°C.).

(b) Providing a flat arch instead of a sprung arch, coupled with hot air nozzles which will push down the hot gases to the bottom of the load (Figure No. 12).

(c) Withdrawing gases from the cooler portion of the preheat zone and pushing it into the hotter parts, thereby, creating necessary recirculation.

(d) Providing burners with venturi blocks to create the desired turbulence.

Figures No. 11 and No. 13 show typical cross sections of a furnace zone. The arch in the zone is usually a sprung type of arch to provide adequate space on top of the ware for the expansion of gases and achieve proper combustion. The burners are located in the sidewalls at

TYPE OF KILNS - Continued

B. Continuous Kilns - Continued -

(d) - Continued -

various elevations and fire into the fire lanes (known as index spaces) provided in the setting pattern (Figures No. 11, No. 14 and No. 16).

The kiln shown in Figure No. 11 uses the down the tunnel type of recuperative principle wherein fuel is introduced under pressure through the burners, which in turn mixes with the stream of heated air passing down the length of the kiln from the cooling zone towards the entrance of the kiln. This air by the time it reaches the furnace zone is preheated by the recuperation of heat from the cooling ware.

The other type of recuperative principle is the flue type of recuperation as shown in the kiln in Figure No. 13. In this design a high temperature secondary air flue is provided in the furnace zone kiln wall. This flue is connected with the interior of the furnace zone at the burner position and also at a point at the beginning of the cooling zone using specially designed burners with venturi throats. The hot secondary air is thus inspirated from the hot air flues by the injecting force of the primary fuel air mix. This type of recuperative

TYPE OF KILNS - Continued

8. Continuous Kilns - Continued -

principle is especially desirable where a closed atmosphere control conditions are required as in the case of the firing of some of the basic refractories.

The cooling zone is designed in several ways depending upon the characteristics of the product. Usually, immediately following the furnace zone and at the beginning of the cooling zone there is a rapid cool zone wherein the ware is rapidly cooled from the soaking temperature down to approximately 1200°F. to 1400°F. (650°C. to 750°C.). This rapid cooling is accomplished by the jet cooling principle wherein jets of cool ambient air entrains the hot gases from inside the kiln and then recirculates the blended air. The rapid cooling zone is followed by slow cooling or controlled cooling of the ware either by the indirect cooling method or by direct contact of the cooling air forced into the kiln through a blower located at the exit end of the kiln.

Uniformity of cooling is achieved by providing recirculating fans in the arch.

SUMMARY

The following is a brief summary of the firing practices employed for firing refractories based on product classifications:

A. Low Heat Duty, Moderate Heat Duty, High Heat Duty and certain Super Duty products.

(i) Type of Kilns Used - Mostly Tunnel Kilns, Periodic Kilns and Shuttle Kilns.

(ii) Temperature of Firing - Cone 12 to Cone 14.

(iii) Cycle - 50 to 75 hours in Tunnel Kilns; 120 - 140 hours in Periodic Kilns (Sometimes as high as 240 hours).

(iv) Fuel Consumption - The fuel consumption in a tunnel kiln is 25% to 30% that of a periodic kiln.

B. Super Duty and High Aluminas including Mullite and Tabular Alumina products.

(i) Type of Kilns Used - Mostly Tunnel Kilns and Shuttle Kilns depending upon the volume of production; Periodic Kilns are also employed.

(ii) Temperature of Firing - Usually Cone 19 burn; Cone 23 burn in the case of Mullite based products and Cone 30 to 31 burn for Tabular Alumina based products.

(iii) Cycle - 45 to 60 hours in Tunnel Kilns and Shuttle Kilns. 120 - 150 hours in Periodic Kilns.

SUMMARY - Continued

B. - Continued -

(iv) Fuel Consumption - Fuel consumption depending upon the temperature of firing. The fuel consumption in the Tunnel Kiln is 1/2 to 1/3 that of a shuttle kiln.

C. Silica Refractories

(i) Type of Kiln Used - Most commonly used kilns are the Periodic Kilns; however, the present trend is towards the use of shuttle kilns as well as Tunnel Kilns. Tunnel Kilns are more and more being used for firing of silica bricks.

(ii) Temperature of Firing - Cone 16 to 18 burn.

(iii) Cycle - 120 to 150 hours in a Tunnel Kiln and Shuttle Kiln as compared to three (3) weeks to one (1) month in a Periodic Kiln

(iv) Fuel Consumption - Figures not available. However, consumption in a Tunnel Kiln will be considerably less than that of a Shuttle or Periodic Kiln.

Note: It is to be noted that in the past when Periodic Kilns were employed for the firing of silica bricks, the temperature raise had to be done very gradually on account of the inversion of silica mineral. The rate had to be slow

SUMMARY - Continued

C. Silica Refractories - Continued -

(iv) Fuel Consumption - Continued -

at first as the uniformity of temperature distribution had to be achieved at every stage. With the use of Tunnel Kilns and Shuttle Kilns the cycle has been drastically brought down. Today even some of the complicated silica coke oven shapes are being fired in the Tunnel Kilns very successfully.

D. Basic Refractories

(i) Type of Kiln Used - Tunnel Kiln is the most commonly used kiln; also Shuttle Kilns where volume of production is low.

(ii) Temperature of Firing - 2600°F. (1430°C.) to 3400°F. (1870°C.) depending upon the type of basic refractory being fired.

(iii) Cycle - 48 to 75 Hours.

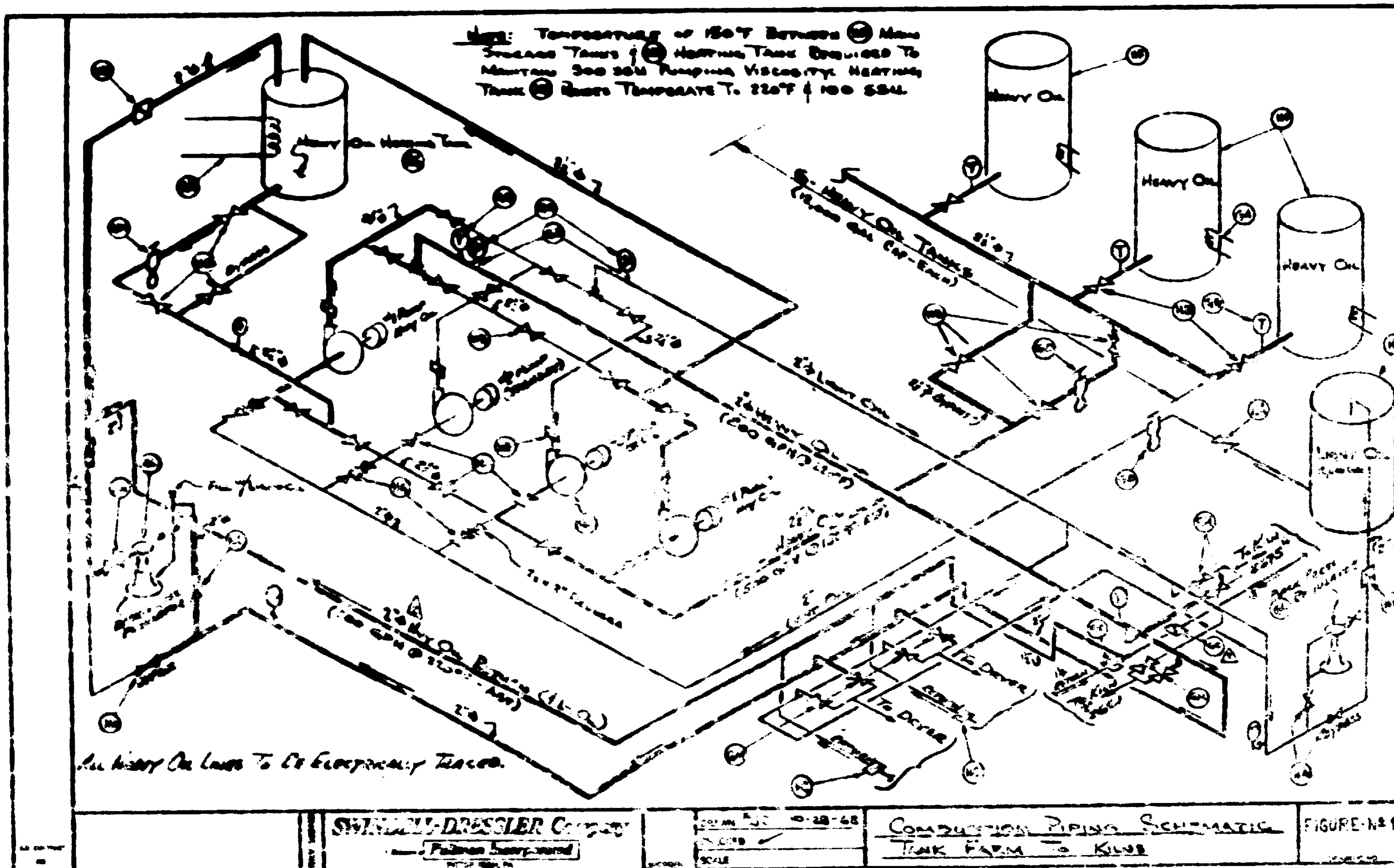
(iv) Fuel Consumption - In a Tunnel Kiln it is about 1/3 that of a Shuttle Kiln at 3200°F. firing temperature (1870°C.).

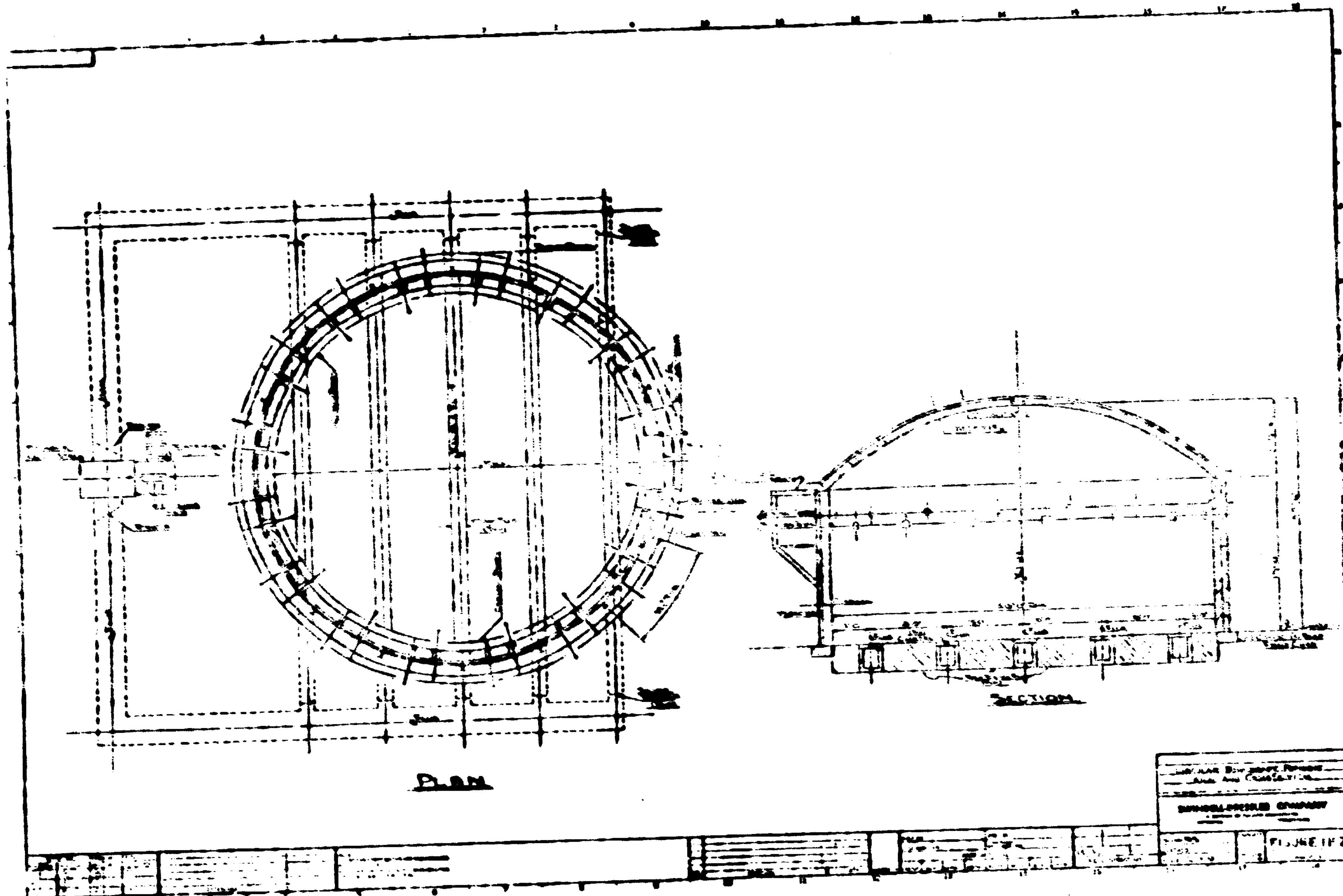
__SUMMARY__ - Continued

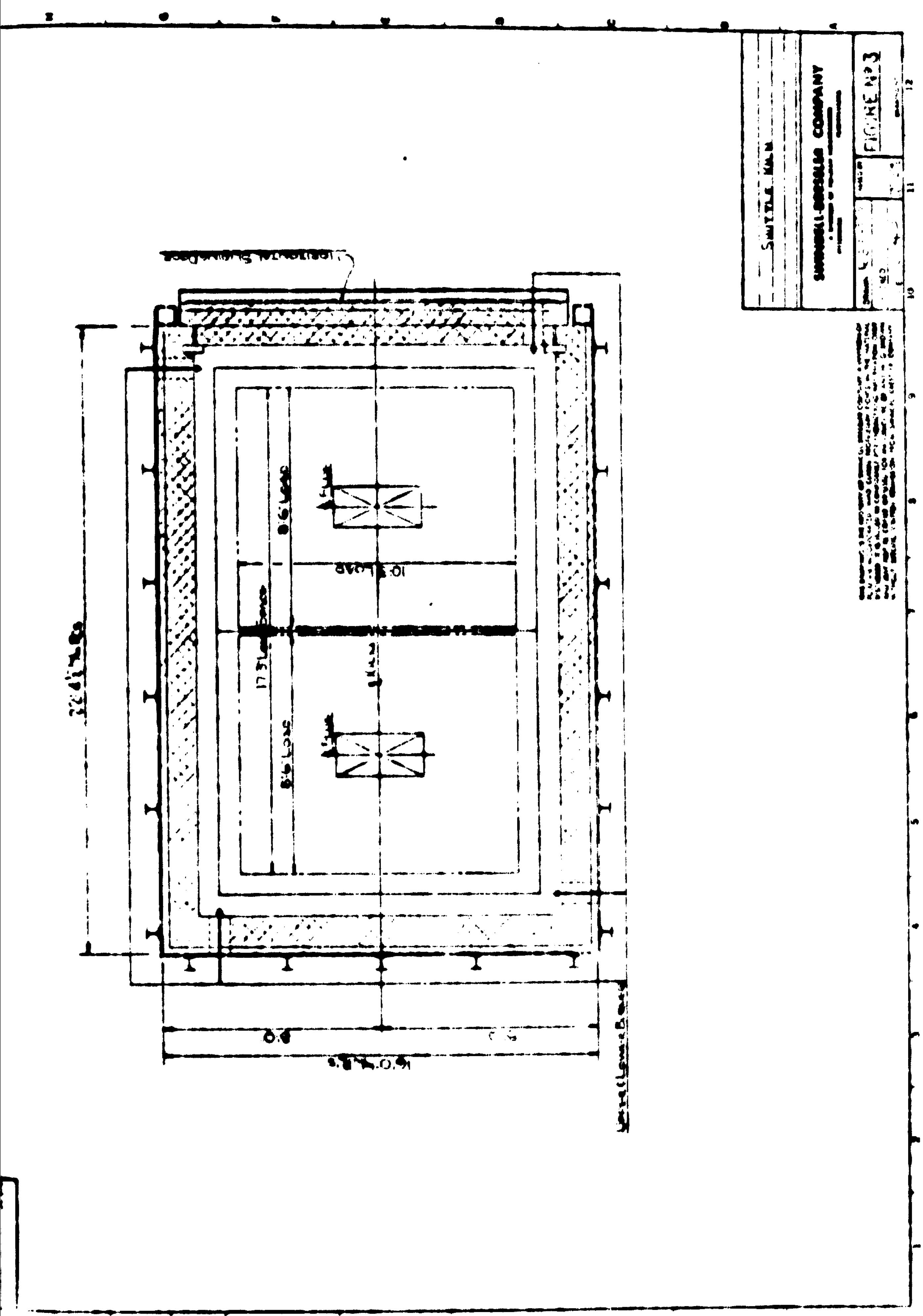
Tunnel Kiln is the most economical method of firing refractories as is evidenced from the above information. The minimum tonnage that can be econmically fired in a Tunnel Kiln is 400 tons per month or approximately 5,000 tons per year. For higher tonnages the economy improves considerably.

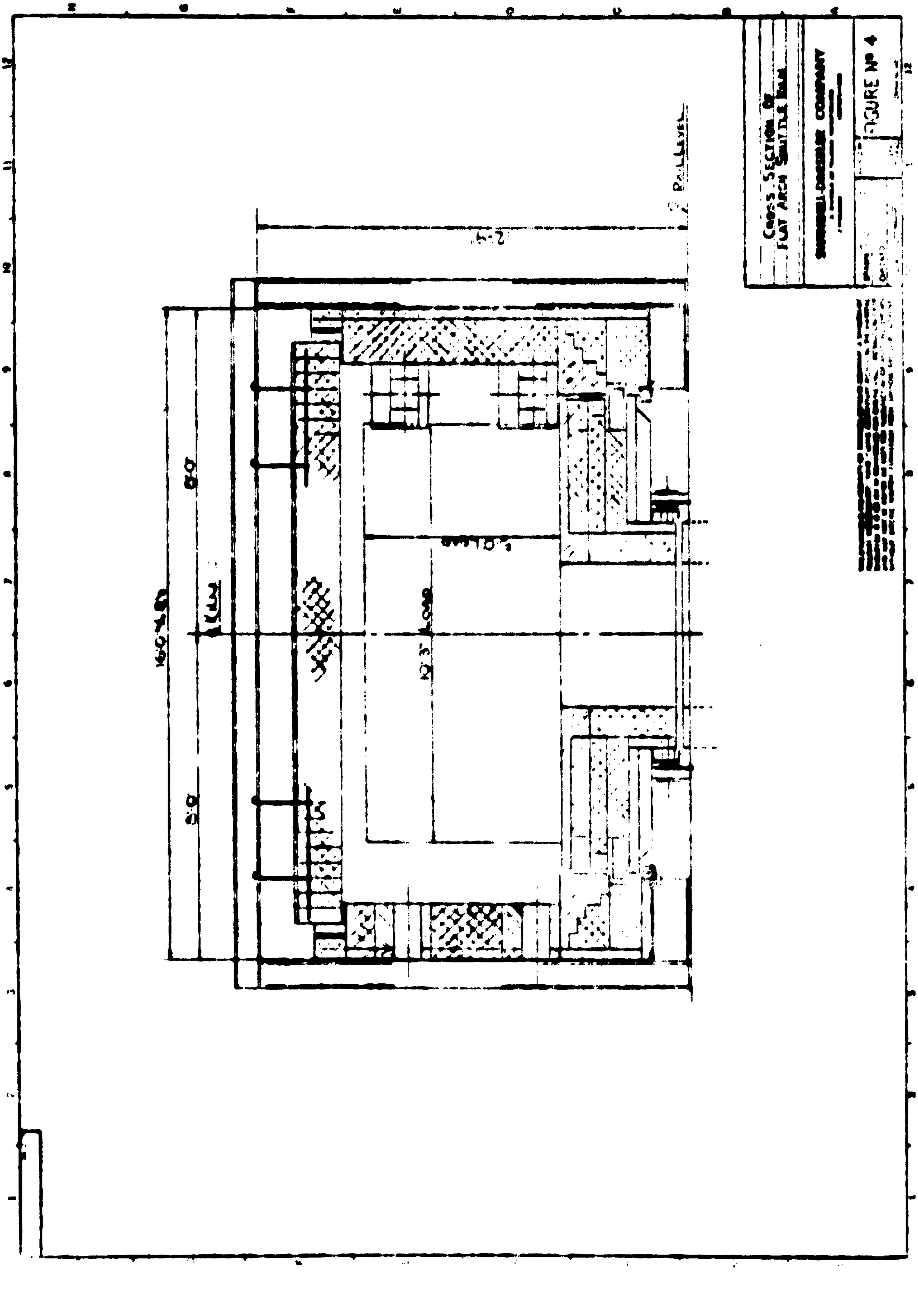
For the production of grog and for dead burning of basic raw material like Dolomite and Magnesite, both Rotary and Shaft kilns are used in the Refractory Industry. Whereas, the Shaft Kiln is more economical and the initial capital investment is less than that of the Rotary Kiln, the quality of the final product is not as uniform.

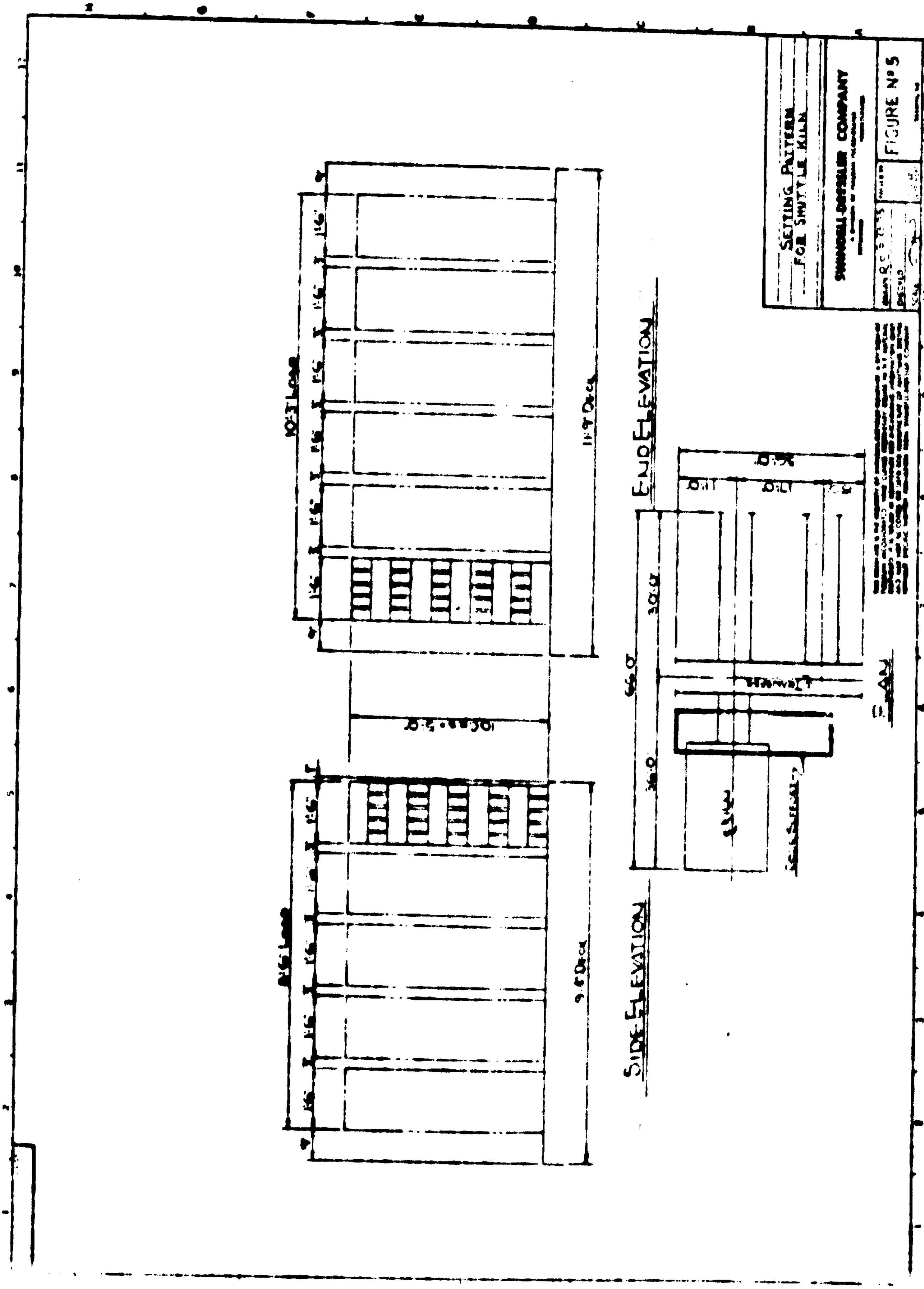
Rotary Kilns were initially used only for producing grog and for the calcination of kyanite. However, these Kilns are now being used for the dead burning of Dolomite as well as Magnesite.


Heavy Oil
Heavy Oil
Heavy Oil
Light Oil
Heavy Oil Heating Tank
Heavy Oil Tanks
2" Light Oil
To Dryer
To Dryer
All Heavy Oil Lines To Be Electrically Traced.
SWINDELL-DRESSLER Company
Pullman Incorporated
Conduction Piping Schematic
Tank Farm To Kilns
FIGURE-Nº 1


PLAN
SECTION

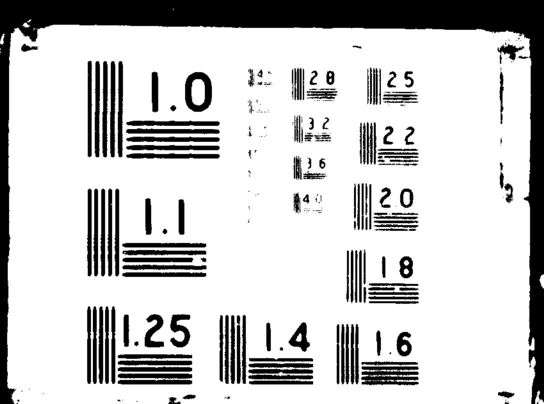

SHUTTLE KILN
COMPANY
FIGURE Nº 3

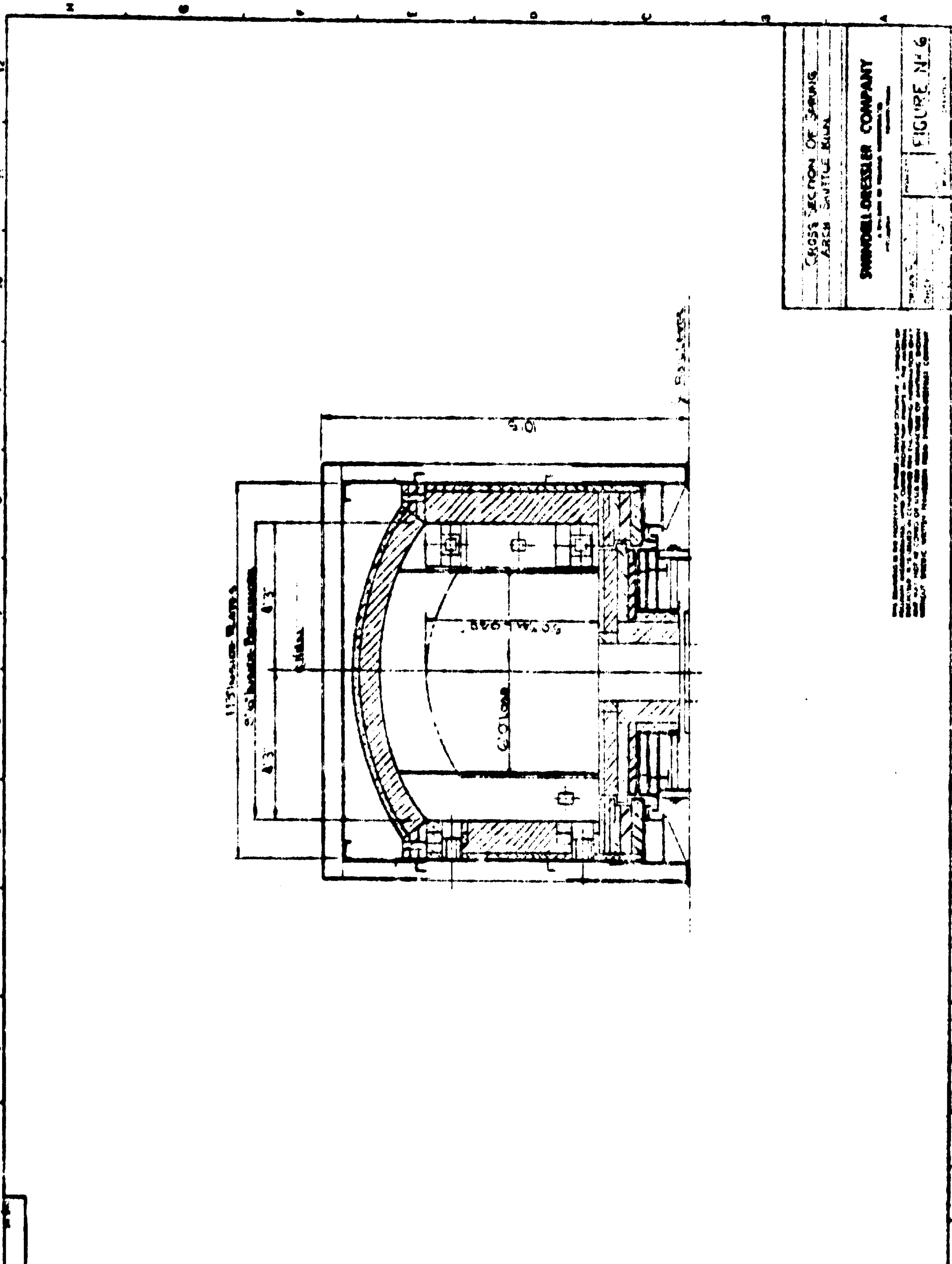

CROSS SECTION OF
FLAT ARCH SHUTTLE
COMPANY
FIGURE No 4
Rail Level
8'-0"
8'-0"

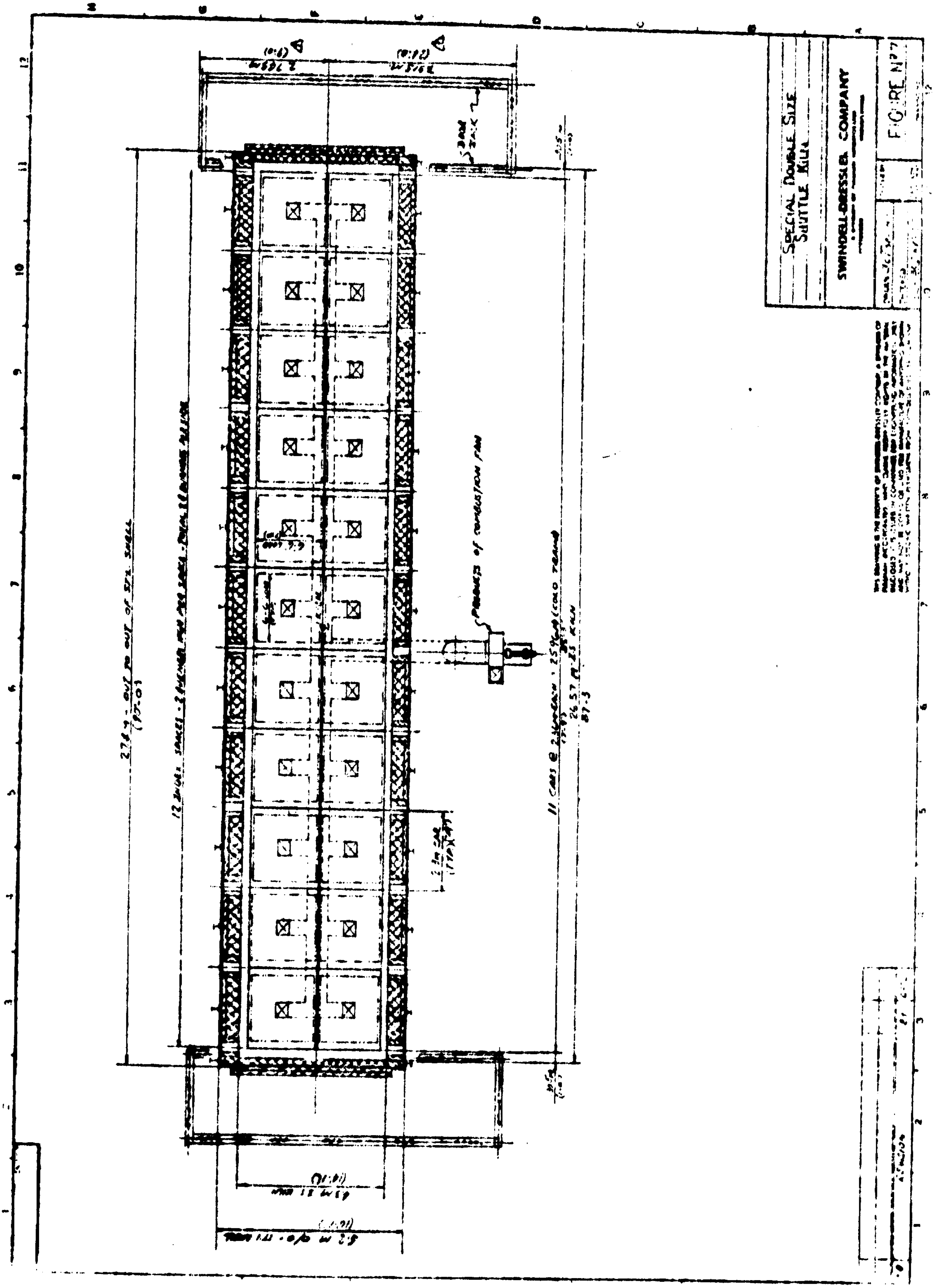

SETTING PATTERN
FOR SHUTTLE KILN
SWINDELL-DRESSLER COMPANY
FIGURE No 5
SIDE ELEVATION
END ELEVATION
PLAN
66'-0"
30'-0"
36'-0"

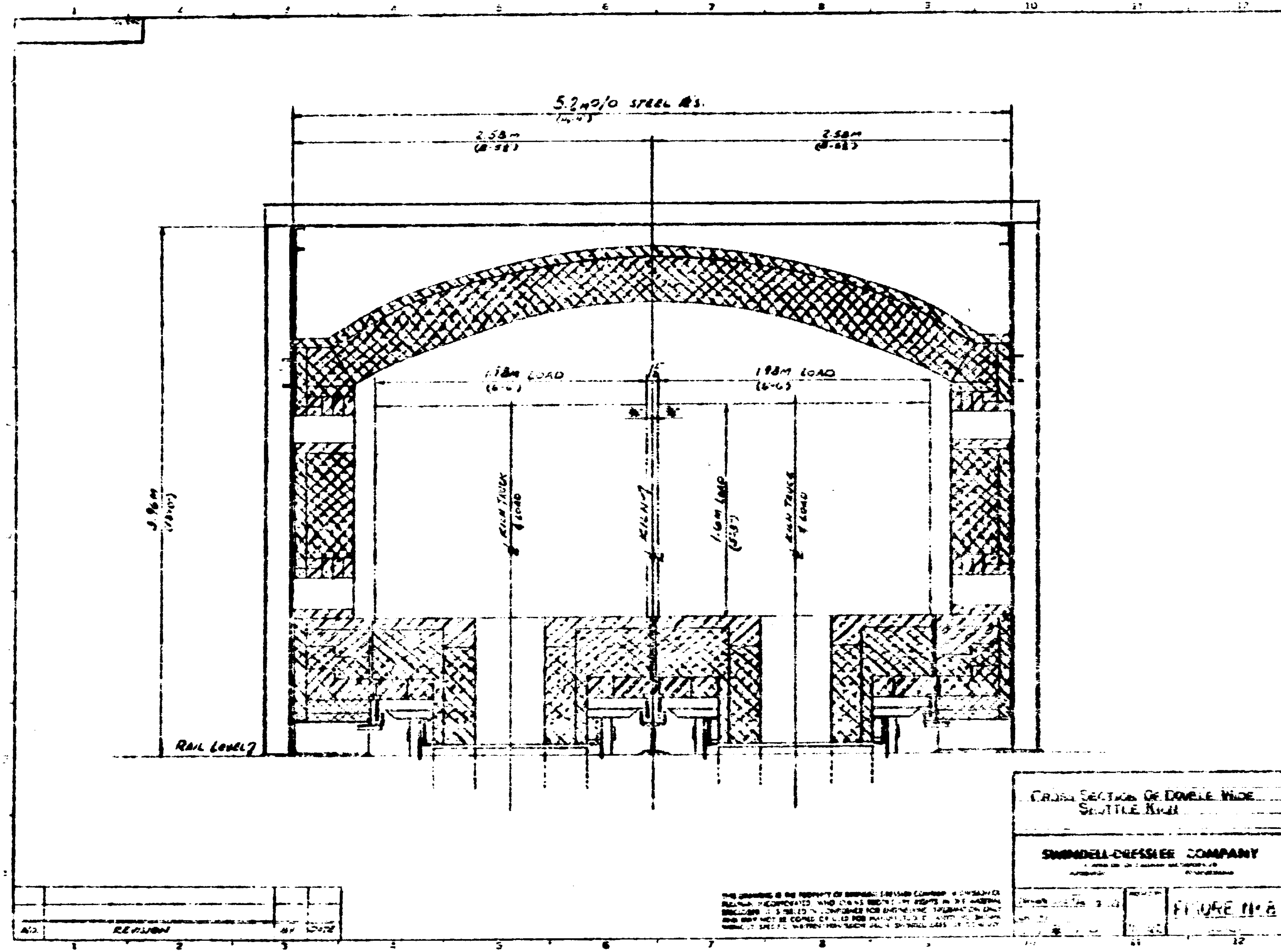
74.10. 1

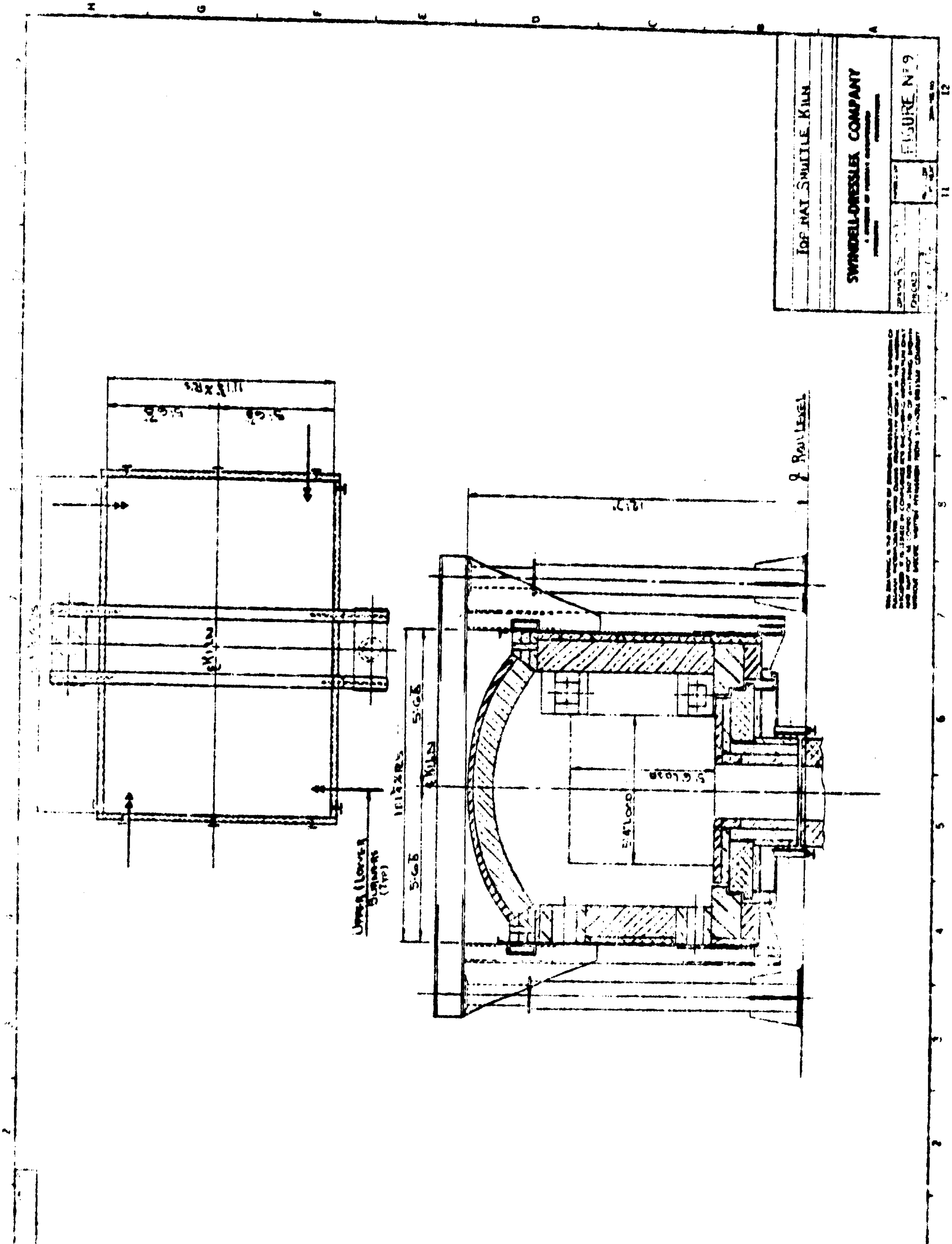
05601

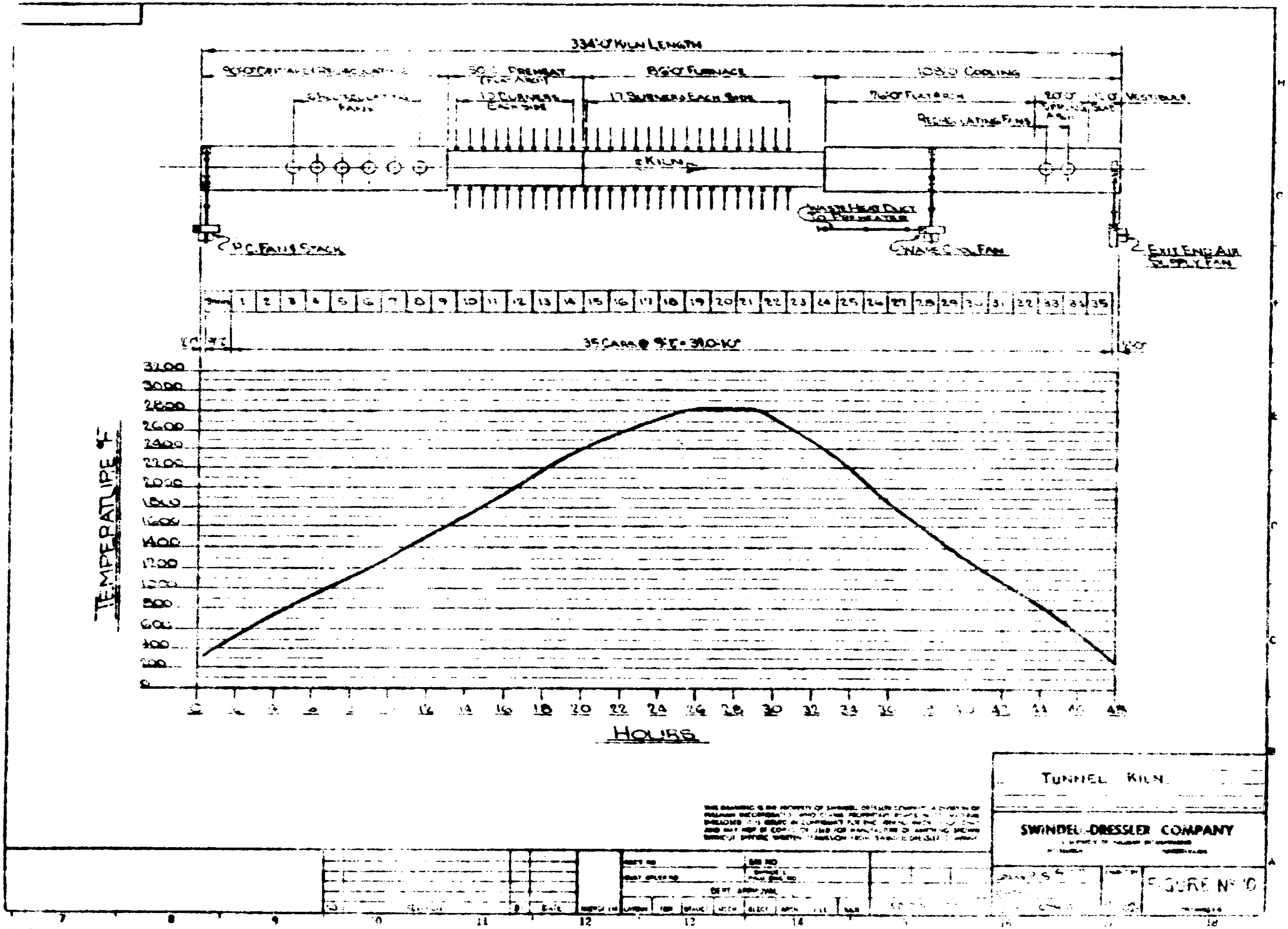


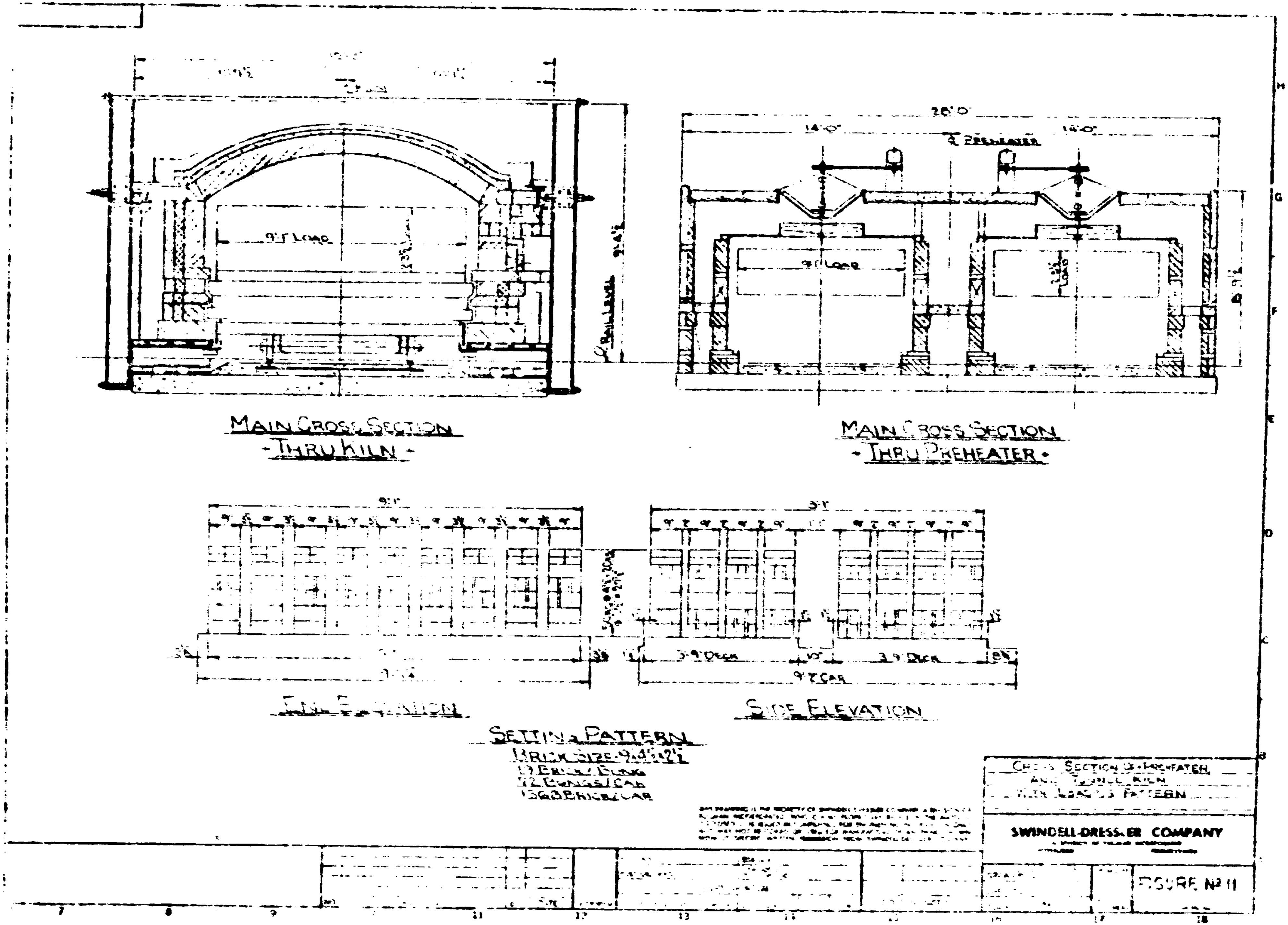

CROSS SECTION OF SPRUNG
ARCH SHUTTLE KILN
SWINDELL-DRESSLER COMPANY
FIGURE No 6
10'-6"
4'-3"
4'-3"

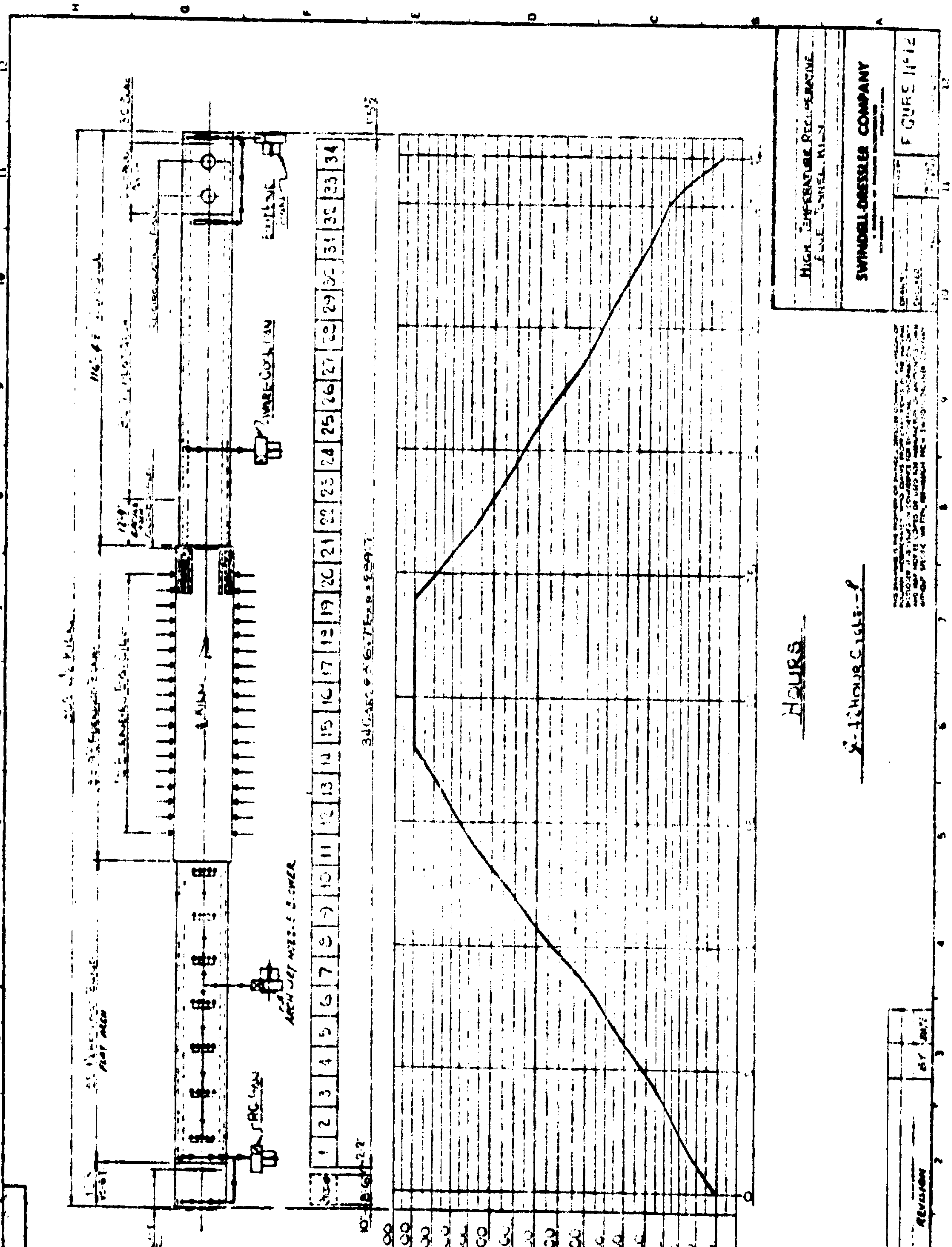

SPECIAL DOUBLE SIZE
SHUTTLE KILN
SWINDELL-DRESSLER COMPANY
FIGURE Nº7
PRODUCTS of COMBUSTION FAN

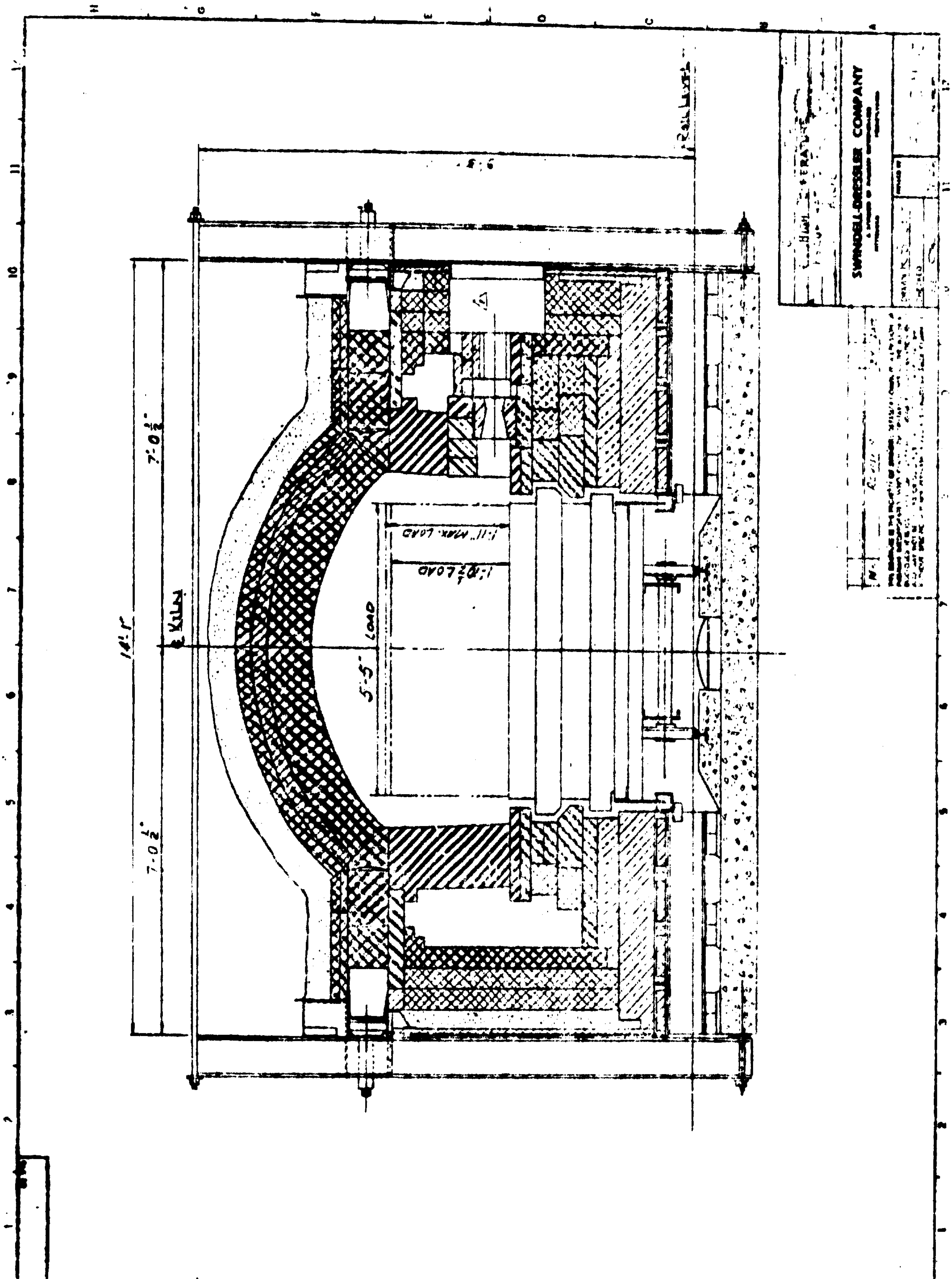

5.2m O/O STEEL B's.
2.58m
2.58m
1.98m LOAD
(6-6)
1.98M LOAD
(6-6)
3.96m
KILN TRUCK ℄ LOAD
KILN ℄
1.6m LOAD
KILN TRUCK ℄ LOAD
RAIL LEVEL
CROSS SECTION OF DOUBLE WIDE SHUTTLE KILN
SWINDELL-DRESSLER COMPANY
FIGURE No. 8
REVISION

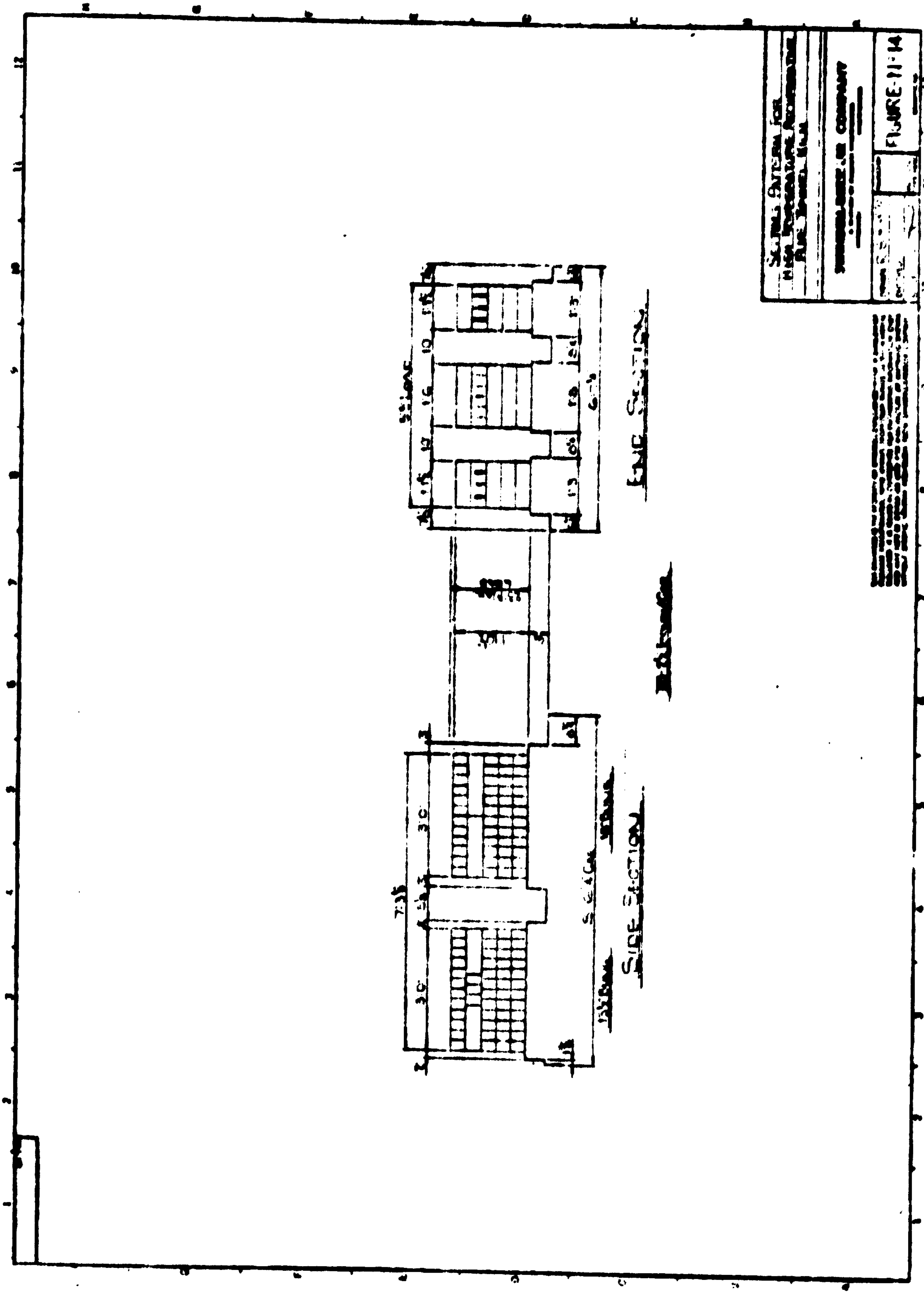

TOP HAT SHUTTLE KILN
SWINDELL-DRESSLER COMPANY
FIGURE No 9
Rail Level
Upper & Lower Burners (Typ)

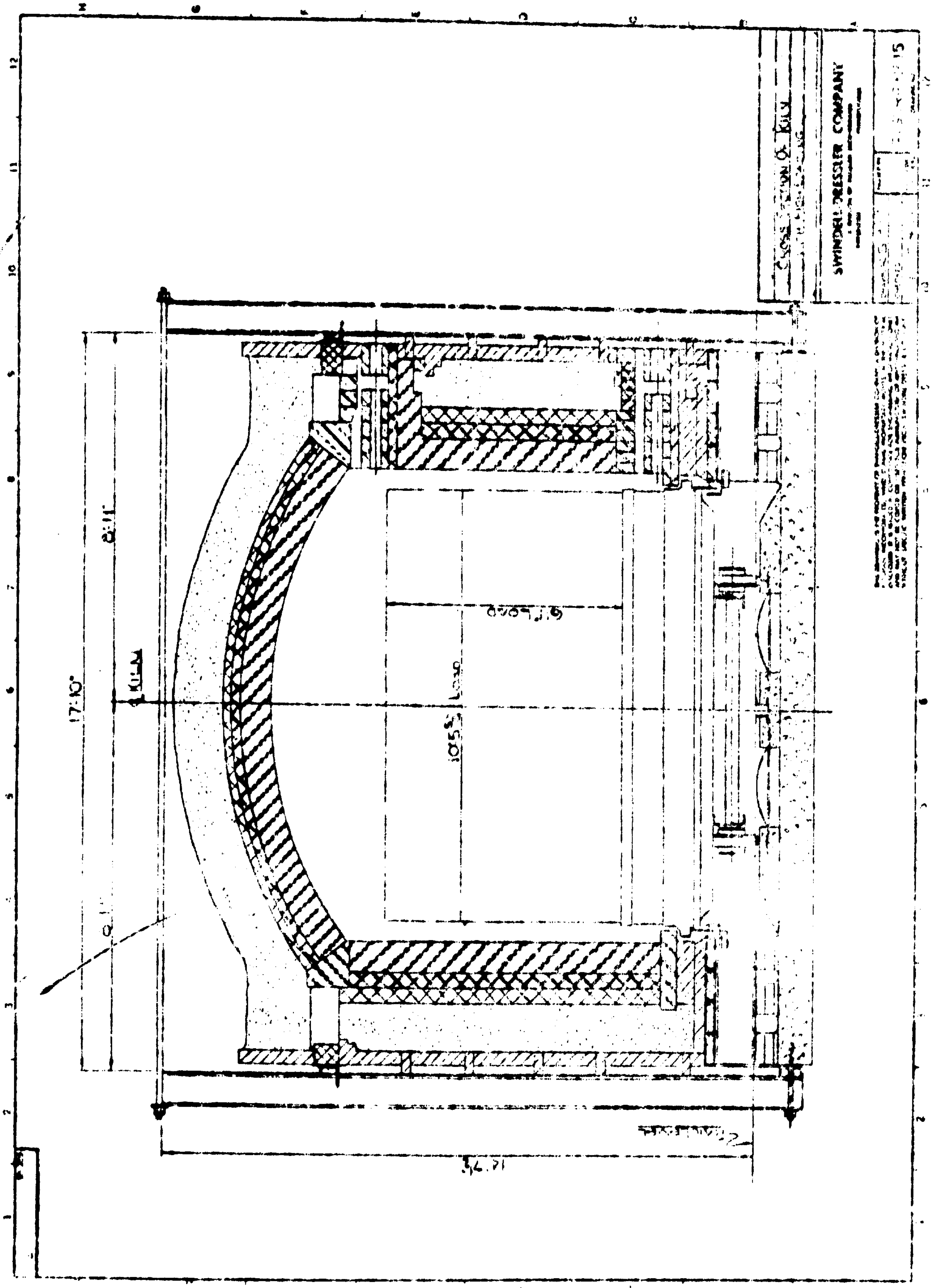

334'0" Kiln Length
50'0" Preheat
85'0" Furnace
108'0" Cooling
12 Burners Each Side
17 Burners Each Side
76'0" Flat Arch
Recirculating Fans
Vestibule
Kiln
Waste Heat Duct to Preheater
P.C. Fans Stack
Exit End Air Supply Fan
35 Cars @ 9'-2" = 320'-10"
Temperature °F
Hours
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
12
14
16
18
20
22
24
26
28
30
32
34
36
42
48
Tunnel Kiln
Swindell-Dressler Company
Figure No 10


9'-5" LOAD
26'-0"
14'-0"
14'-0"
℄ PREHEATER
9'-0" LOAD
MAIN CROSS SECTION
- THRU KILN -
MAIN CROSS SECTION
- THRU PREHEATER -
3'-9" DECK
10"
3'-9" DECK
9'-8" CAR
SIDE ELEVATION
SETTING PATTERN
BRICK SIZE 9x4½x2½
CROSS SECTION OF PREHEATER
SWINDELL-DRESSLER COMPANY
FIGURE Nº 11


HIGH TEMPERATURE RECUPERATIVE
TUNNEL KILN
SWINDELL-DRESSLER COMPANY
FIGURE Nº12
HOURS
TEMPERATURE °F
3400
ARCH JET NOZZLE BLOWER
KILN
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
REVISION


14'-1"
7'-0 1/2"
7'-0 1/2"
5'-5"
LOAD
1'-11" MAX. LOAD
℄ KILN
Rail Level
SWINDELL-DRESSLER COMPANY


SIDE SECTION
END SECTION
FIGURE-11-14


SWINDELL DRESSLER COMPANY
17'10"
8'11"

74.10. 1