Jan. 30, 1968 W. D. STEVENS ETAL 3,366,093

START-UP SYSTEM FOR ONCE-THROUGH VAPOR GENERATORS

Filed Feb. 28, 1966 3 Sheets-Sheet 1

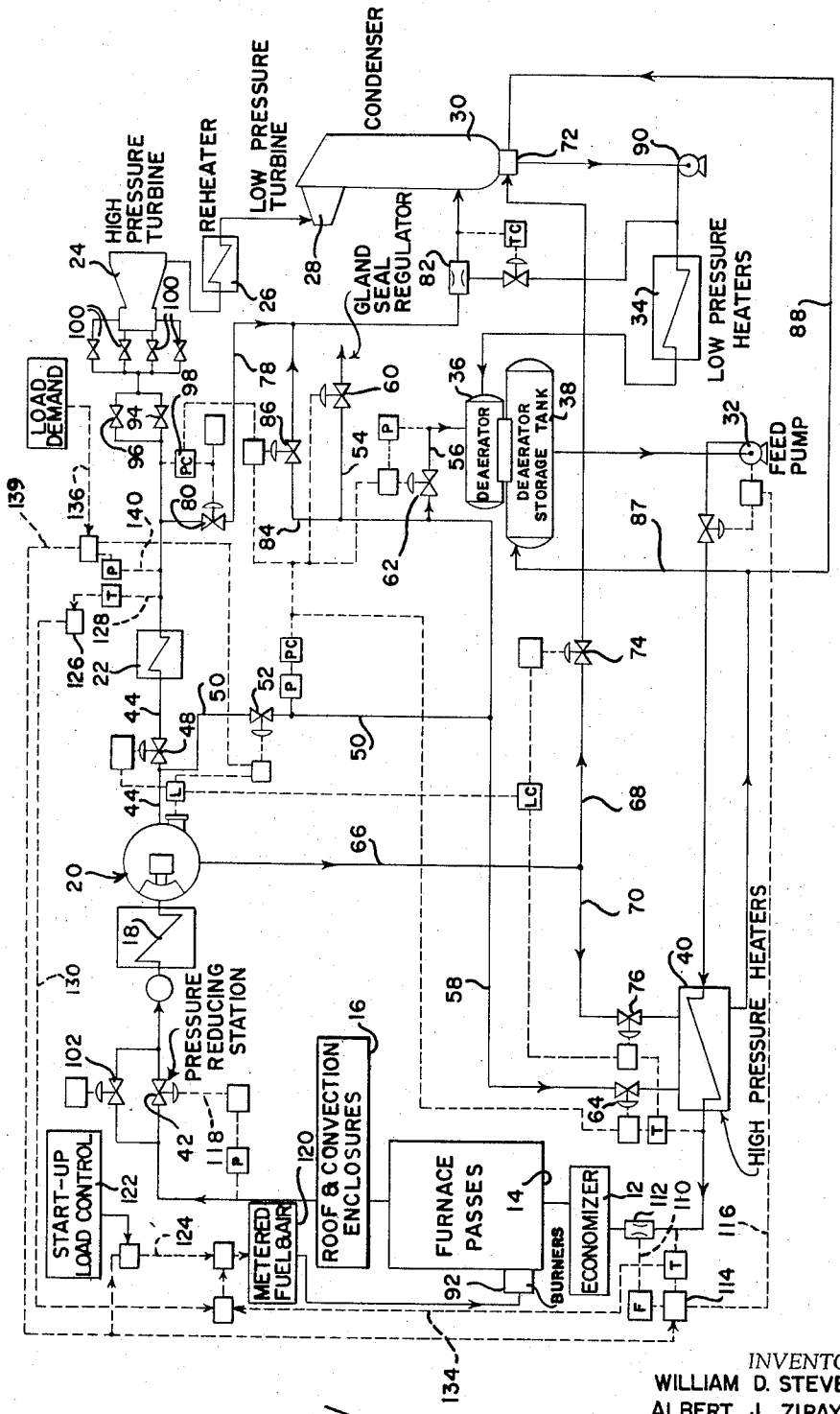


Fig. 1

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START-UP SYSTEM FOR ONCE-THROUGH VAPOR GENERATORS

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Fig. 2

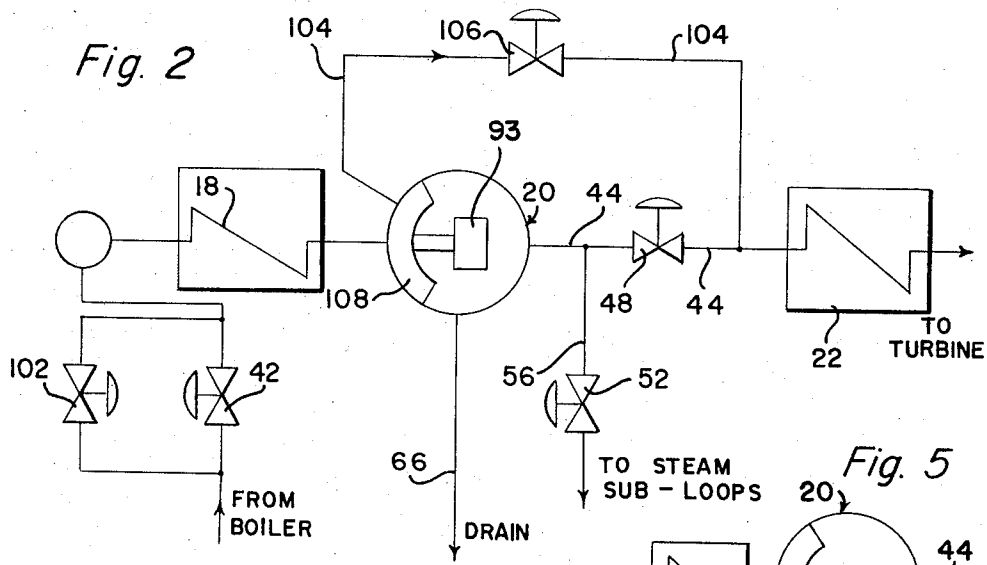


Fig. 5

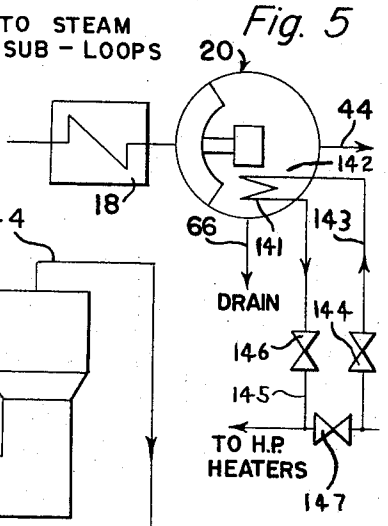
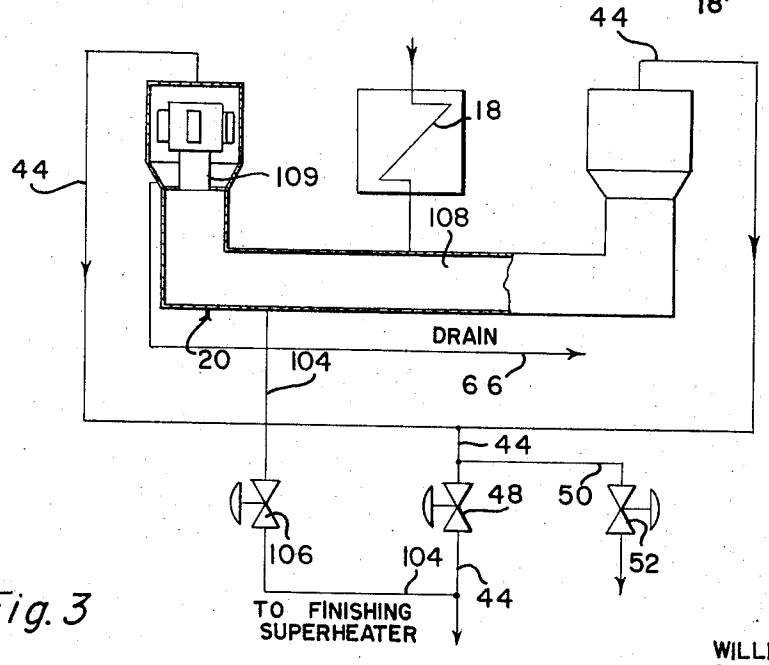


Fig. 3



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Filed Feb. 28, 1966 3 Sheets-Sheet 3

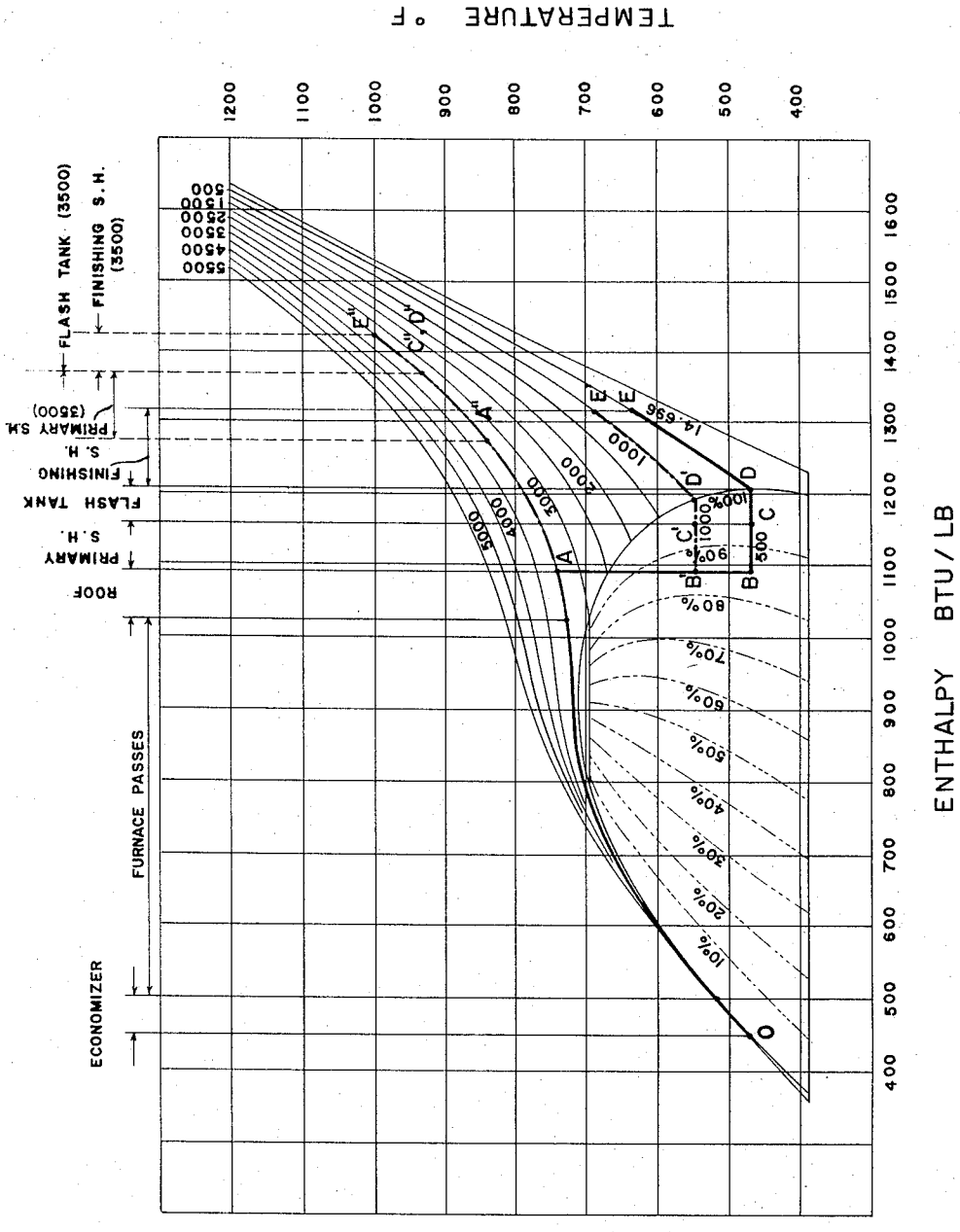


Fig. 4

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United States Patent Office 3,366,093
Patented Jan. 30, 1968

3,366,093

START-UP SYSTEM FOR ONCE-THROUGH VAPOR GENERATORS

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Filed Feb. 28, 1966, Ser. No. 530,613
6 Claims. (Cl. 122—406)

ABSTRACT OF THE DISCLOSURE

A start-up system for a once-through vapor generator wherein a header for one of the superheating sections is enlarged to accommodate a vapor-liquid separator, with flow conduits suitably connected to the header to transmit the vapor and liquid flows to points of use.

This invention relates to a start-up system for vapor generators, and in particular to apparatus for starting up, restarting and low load operation of a subcritical or supercritical vapor generator of the forced flow once-through type.

In once-through units a by-pass system around the turbines protects the furnace circuits and turbines during start-up, passing a minimum flow through the furnace by-passing the turbines (which cannot handle the cold fluid during this period) until flow through the unit is heated sufficiently for admission to the turbine without using the by-pass system. The by-pass system usually includes a flash tank in which flow from the furnace is separated into steam and water, passing at least a portion of the steam to the turbine for early warming and rolling.

In a start-up system certain considerations are important; for example, reducing start-up time and cost; maximizing heat recovery; optimizing steam temperatures and pressure control; matching capabilities for both cold and hot start conditions; changing steam output to meet turbine generator load requirements from initial light-off to full load operation; minimizing thermal shock and high temperature damage throughout the system and in the turbine; and, providing smooth loading of the turbine during the start-up period by supplying the turbine with steam at a pressure and temperature which is gradually increased during the start-up period.

In accordance with these considerations the present invention results in improvements beyond those heretofore achieved. The present arrangement and operation provides an improvement in control and loading of the turbine, as compared, for example, with prior external flash tank systems where the flash tank was external to the main flow line, and where the flash tank was of limited pressure design, considerably less than the full operating pressure of the main pressure parts. In these systems when during the start-up period the turbine demands approached pressures exceeding the design pressure of the flash tank, the flash tank was switched out of operation (since any further increase in flash tank pressure could not be tolerated), and flow to the turbine was supplied directly from the high pressure main flow line upstream of the flash tank. This switch in flow, among difficulties of control, frequently caused a drop in enthalpy at the turbine since the flow source switched from a saturated vapor (from the flash tank) to a lower enthalpy water-vapor mixture (from the main flow line).

To avoid a drastic pressure and temperature drop at the turbine throttle, the main flow line valve (admitting flow to the turbine directly from the main flow line) had to be opened very slowly, the firing rate had to be increased and the flash tank entrance valve had to be gradually closed, slowly transferring the source of turbine steam from the flash tank (which was held at the limited design pressure) to the main flow line.

Furthermore, in these systems, at the limited pressure of the switch-over point, saturated water, as well as saturated steam and mixtures of saturated steam and water, have the same temperature. Consequently, at the switch-over, a temperature measurement would not indicate the state of the liquid, and when switching from the flash tank (with a high saturated vapor enthalpy) to the main flow line (having a lower enthalpy) it was possible for the steam temperature to go down to saturation entering the turbine without knowing whether there was water or steam entering the turbine.

Accordingly, the present invention provides an improved apparatus for starting up a once-through vapor generator which includes a main flow path for conducting flow to a turbine, vapor generating and superheating sections in the main flow path, an enlarged header capable of full pressure operation connected to one of the superheating sections, and vapor-liquid separation means in the header. Vapor and liquid by-pass lines lead from the vapor and liquid spaces of the enlarged header to points of use with valves therein to close off the by-pass lines. At full load, as well as during start-up, flow is through the main flow path including the furnace and the enlarged header flash tank.

A pressure reducing station also is disposed in the main flow path upstream of the header separator. In operation, the furnace section is at normal full load operating pressure substantially throughout the start-up and full load periods, while the header separator is at variable pressure during start-up, gradually increasing from a substantially reduced pressure to normal full load operating pressure.

With this apparatus the benefits of full pressure operation in the furnace and reduced pressure operation downstream of the furnace may be realized during start-up, while permitting the flow to always pass through the flash tank separator, eliminating the need for separator switch-out. Full pressure furnace operation and reduced pressure flash tank operation during start-up permits vapor to be flashed in the flash tank early in the start-up cycle for warming and rolling of the turbine and other uses; also, heat is imparted to the circulating fluid at a lower fluid pressure for better heat transfer contributing toward reducing start-up time. With the present invention, vapor, when produced, can always pass through the flash tank (since it is capable of full pressure operation), and during an early start-up period, at least a portion of this vapor is passed from the flash tank to a finishing superheater supplying the turbine with superheated vapor. Later in the start-up period, the pressure at the turbine and consequently in the flash tank is gradually raised to full operating pressure while the vapor continues to pass through the flash tank separator and then to the finishing superheater and turbine. This provides superheated vapor and higher enthalpy quicker during this period of start-up; in the prior external flash tank systems, during this equivalent period, the flash tank was held at its limited design pressure and vapor was sent to the turbine from another source, i.e., directly from the main flow line upstream of the flash tank. There vapor from the main flow line was not assured of being passed to the turbine in a highly superheated state.

With the present invention, the difficulties of the prior external flash tank systems are avoided. During start-up, the enthalpy at the turbine never decreases since no switch-over occurs and the loading is continually through the flash tank, the flash tank always providing saturated steam to the finishing superheater and turbine. Conse-

quently steam without water is assured to the turbine. This permits the turbines to be smoothly loaded at pressures (and temperatures) that constantly and gradually increase without going through any transfer from an external source of steam, and consequently without any upset in pressure and/or temperature.

Also in accordance with the apparatus of this invention, flash tank pressure (and consequently throttle pressure) may be raised to full operating pressure during start-up over any desired load range, for example, from a low load until the load to the turbine reaches any other predetermined load including full load, or a load equal to the minimum start-up flow necessary to keep the furnace cool. Flexibility is achieved providing a controllable start-up for optimum performance over variable system requirements.

Another advantage of the present invention is the elimination of costly control and stop valves, safety valves, piping and a separate pressure vessel. In prior systems, where the flash tank was external to the main flow line, there was required, in addition to a separate flash tank vessel and additional piping, two control and stop valves. One was a flash tank admission valve for passing fluid from the furnace into the external flash tank (by-passing the main flow line and turbine) and subsequently for controlling the turbine pressure; and the other was a vapor return valve for passing steam, separated in the flash tank, back to the main flow line to the finishing superheater and turbine. During later start-up periods, the increasing main flow line pressures exceeded the flash tank design pressure and both of these valves were closed removing the flash tank from service. Safety valves had to be provided on the flash tank vessel in the event the admission valve fails to open during this period tending to cause the pressure in the flash tank to increase beyond its rated capacity; the safety valves would, in that event, relieve the high pressure flow dumped from the main flow line. With the full pressure design flash tank of the present invention, the flash tank is integrated into the main pressure flow line, the flash tank being one of the reheater (or primary superheater) headers; flow is always through the flash tank during start-up as well as during full load, during reduced pressure as well as full pressure operation; and consequently, the need for the aforementioned valves is eliminated.

The pressure reducing valves, located between the furnace and the primary superheater maintain desired full pressure operation of the furnace during start-up (for optimum cooling and protection of the furnace heating surfaces) and together with the control valves in the second by-pass loop, provide reduced pressure operation of the enlarged primary superheater header and flash tank (for optimum start-up performance), while permitting the flash tank to be disposed in the main flow line in the reheater header; because with this arrangement the flash tank admission valve of the prior external flash tank systems which was located between the reheater header and the external flash tank and which served to reduce the pressure in the flash tank during start-up, can be eliminated.

The present invention is also advantageous in a hot restart. For a hot restart it is important to match the hot temperatures in the turbine as soon as possible. This is quite the opposite of a cold start, where the turbine is cold and hot fluids are gradually admitted at a specified rate to gradually heat up the turbine. For example, during the cold start, the control system is set up to deliver initial steam to the turbine at a relatively low temperature. For the hot restart, the controls are set up above this temperature compatible with the temperature in the main steam pipe supplying steam to the turbine. Immediately on hot restart, the controls operate the combustion firing rate to get the steam up to that temperature. In the prior systems, steam was supplied to the turbine, for example, from the external, limited pressure design flash tank, and then gradually, the pressure was raised up to the design limits of the flash tank before the steam was transferred directly from the main flow line to the turbine, entailing time consuming steps as well as the aforementioned switch-over difficulties. The present system goes directly to as high a pressure that the turbine can stand entirely through the main flow line avoiding going through such a gradual rise in pressure and switch-over.

The invention and the above and other advantages of the invention will become apparent upon consideration of the specification and accompanying drawings, in which:

FIGURE 1 illustrates schematically an embodiment of a start-up system in accordance with the invention;

FIGURE 2 shows the flash tank section of the system of FIG. 1 further including a full load by-pass line;

FIGURE 3 shows an alternate scheme for the flash tank header having a vertical separating capability with a full load pressure reduction line;

FIGURE 4 is a temperature-enthalpy diagram illustrating the operation of FIG. 1; and

FIGURE 5 shows the flash tank header containing a heat exchanger.

Referring now to the embodiment of FIG. 1, there is illustrated schematically a vapor generating and turbine installation start-up system which includes a main flow line comprising in series an economizer **12**, furnace passes **14**, and roof and convection enclosure passes **16**. Also constituting sections of the installation are a primary and/or platen superheating section **18**, a flash tank **20** constituting the outlet header of the primary superheater, and a finishing superheating section **22**. During normal operation of the unit, the flow is through the main flow line, the superheating sections, flash tank, and from the outlet of the finishing superheating section **22** to a high pressure turbine **24**, the exhaust steam from the turbine being reheated at reheater **26** and passed to a low pressure turbine **28**, and from there to a condenser **30**. Being of the once-through type, the system is pressurized by a feed pump **32**, the feed flowing from the condenser through low pressure heaters **34**, deaerator **36** (if one is used), storage tank **38** and high pressure heaters **40** to the economizer **12**.

The start-up system includes a pressure reducing station **42** (which may constitute a plurality of valves, although, only a single valve is shown) in the main flow line upstream of the primary superheater **18** receiving flow from the roof tubes **16**.

The piping and valves for the distribution of the flow from the flash tank consist of a line **44** extending from the flash tank to the inlet end of the finishing superheater **22**, this line containing a main flow line valve (or valves) **48**; and a vapor by-pass line **50** controlled by a vapor line valve **52** leading from line **44** (or from the vapor space of the flash tank) including branches **54** to the turbine gland seal regulator **56** to the deaerator, and **58** to the high pressure heaters, these lines being opened and closed by valves **60**, **62** and **64** respectively. Drain flow from the flash tank is handled by a drain line **66** having branches **68** and **70** leading to the condenser hot-well **72** and to the high pressure heaters **40**, respectively, these lines being opened and closed by valves **74** and **76**, respectively.

Also constituting part of the by-pass system is a line **78** leading downstream of the outlet of the finishing superheater **22** to the condenser, by-passing the high pressure and low pressure turbines, a pressure reducing valve **80** in the line, and a spray attemperator **82** immediately upstream of the entrance for the condenser. The line **78** is joined by a branch line **84**, from the flash tank vapor space through valve **86**.

Although in the following example, specific numbers are given with respect to pressures, flow rates, temperatures and the like, it is to be understood that the invention is not limited thereto.

Initial heating of the once-through unit

Initially, in a cold start-up, the feed pump **32** is driven to pressurize the unit upstream of the reducing station **42**,

and the minimum fluid flow necessary for cooling the high pressure circuitry is established through the unit in the furnace to the primary or platen superheater outlet header (which also comprises the flash tank **20**). Since the cold fluid cannot enter the turbine, the output from the primary superheater is fed from the flash tank **20**, and through the flash tank drain line **66** to the high pressure heaters and condenser hot-well.

In this example, a minimum flow rate of 30% of full load flow through the unit is required for satisfactory cooling of the high pressure circuitry. The pressure upstream of the reducing station is initially held at 600 p.s.i., and the fluid is throttled through the reducing valves **42** to a pressure of about 100 p.s.i. The upstream pressure is initially held at 600 p.s.i. to eliminate the serious erosion of the valves associated with high pressure drops and cold fluid temperatures.

The high pressure heaters drain to the deaerator storage tank **38** through line **87** and/or to the condenser through line **88**. The condensate from the condenser is pumped by the condensate pump **90** through the low pressure heaters **34** to the deaerator **36** and then to the deaerator storage tank **38**. At this time, the main flow line valve **48**, between the flash tank and inlet end of the finishing superheater **22**, is closed so that no flow passes through this valve to the turbines. Also closed is the turbine by-pass line valve **80**, between the outlet end of the finishing superheater **22** and the condenser **30**. Further, at this stage of start-up, the vapor lines from the flash tank are closed by valves **52, 60, 62, 64** and **86**. Valves **74** and **76** are open to permit liquid draining.

The burners **92** are then put into operation, for example, at about 15% of full load firing rate, controlled so that the furnace exit gas temperature entering the area of the finishing superheater does not exceed 1200° F., the maximum safe temperature for the tube metal.

When the fluid temperature upstream of the reducing station **42** reaches a predetermined temperature, for instance about 350° F., the reducing valves of the station are adjusted to increase the upstream furnace pressure from 600 p.s.i. to 3550 p.s.i. (2550 in a subcritical unit). At this point, the flow remains at 30% and no significant steam quantity is flashed in the flash tank; but as heating is continued, at constant pressure and flow, steam flashing will take place in the flash tank in increasing quantities, the steam being separated from the liquid while passing through the flash tank separating internals **93**, and a flash tank level will be established at about 250 p.s.i. in the flash tank.

As a level is formed in the flash tank, valve **52** is opened permitting separated steam to pass through the vapor by-pass line **50** leading to valves **60, 62, 64** and **86** respectively in the branch lines, **54** (to the gland seal); **56** (to the deaerator); **58** (to the high pressure heater) and **84** (to the condenser), providing heat recovery. As the flash tank pressure builds up valves **60, 62** and **64** in turn open (deaerator pressure control on valve **62** overrides flash tank pressure control). At the flash tank set point value of about 500 p.s.i, valve **86** opens as necessary to hold this pressure. The flash tank pressure is then controlled at this pressure until 5% turbine load is achieved. The main flow line valve **48** in line **44** leading from the flash tank vapor space to the inlet of the finishing superheater **22**, opens to furnish warming steam to the main steam line, turbine stop valve by-pass valve **94** and stop valve **96** at the entrance to the turbine **24** being closed.

The subsequent rise in pressure in the main steam line opens valve **80** (in response to PC **98**) in the turbine by-pass line **78** allowing the warming steam to pass to the condenser **30**. Up to 5% load valve **52** is wide open and valves **80** and **86** hold the desired pressure at the turbine to 500 p.s.i.

All of the flash tank drain flow is still routed through the valves **76** and **74** to the high pressure heaters and the condenser hot-well for additional heat recovery. Valves **76** and **74** respond to level control (LC) to hold the desired flash tank liquid level.

Initial turbine rolling

The turbine stop valve by-pass valve **94** is opened to permit warming and rolling of the turbine using a portion of the steam passing through valve **48** and the finishing superheater for the warming and rolling, the remainder being disposed of through the by-pass line **50** leading from the vapor space of the flash tank. The warming and rolling flow from the outlet of the flash tank, to the high pressure turbine through the finishing superheating section is superheated in the finishing superheater.

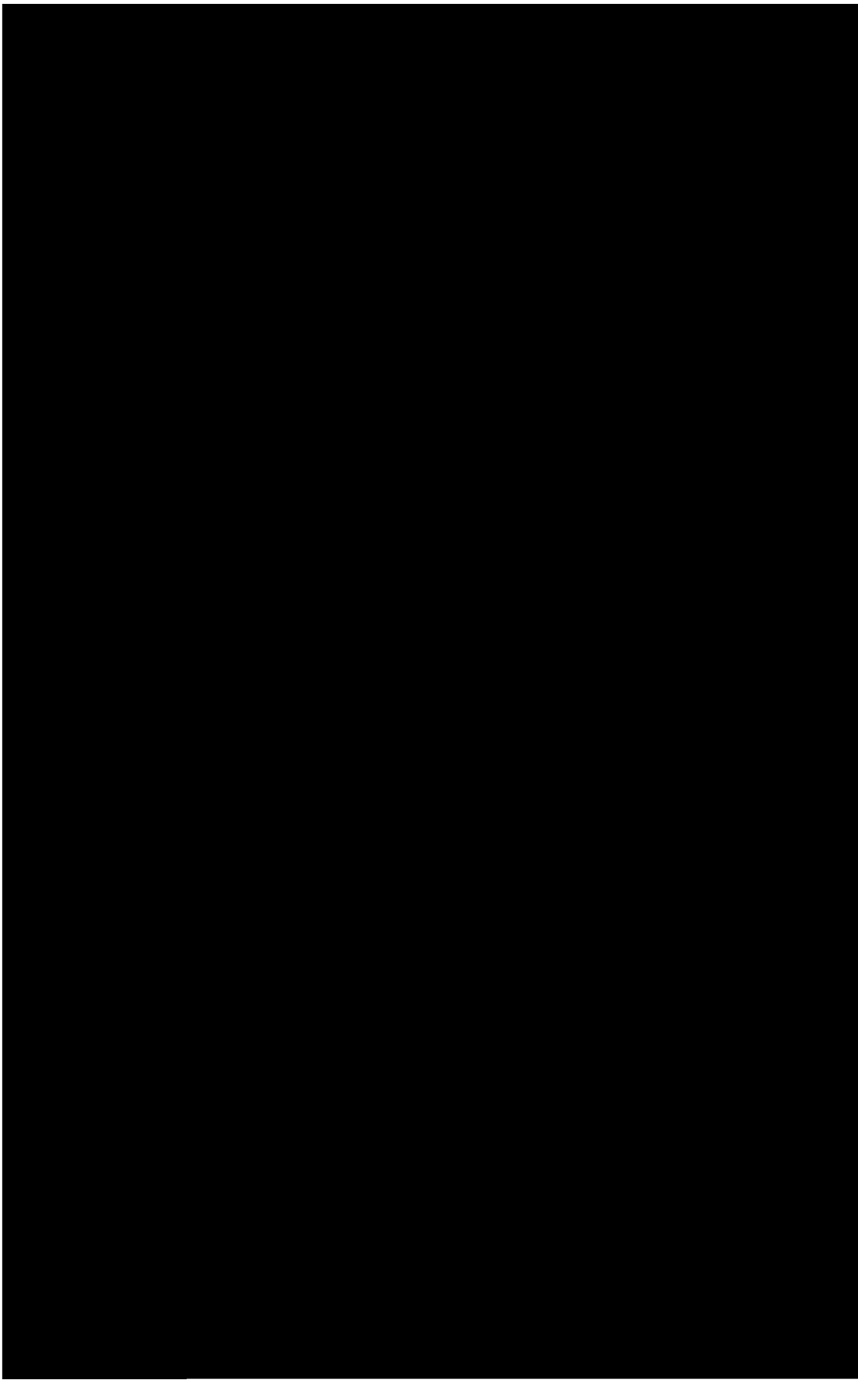
A typical high pressure steam turbine unit includes the main throttle stop valve **96**, and a plurality of governor control valves **100** in series with the stop valve. Associated with the stop valve is the by-pass control valve **94**, for control of the flow at low loads. Valve **94** is cracked open to pass steam to the high pressure turbine by regulating the closure of valve **80**. This regulation of valve **80** is accomplished by some index of flow to the turbine, for example, the position of valve **94** or the first stage turbine pressure. With this type of regulation the flow to the turbine is transferred from that flowing through valve **80**. This maintains a constant flow through the finishing superheater and therefore maintains the fluid entering the turbine at constant temperature. Accordingly line **78** and valve **80** permit vapor flow to be supplied to the turbine at a heat level for maximum protection of the turbine parts. At this stage, the turbine throttle stop valve **96** is closed and the by-pass valve **94** controls the flow to the turbine, reducing the pressure of the flow to about 50 p.s.i.

During the final stages of heating of the generator with turbine throttle pressure held at 500 p.s.i., and prior to loading, the firing rate is maintained at a rate to obtain the required throttle steam temperature. Furnace exit temperature still is monitored not to exceed 1200° F., and the 2 to 5% rolling flow for warming the turbine is maintained from the flash tank to the finishing superheater and to the high pressure turbine. A steady-state condition for the generator is achieved when the enthalpy is approximately 1050 to 1100 B.t.u./lb. entering the flash tank at which point the generator circuit components are up to temperature at the flow rate, firing rate, and pressure set in the unit. Turbine throttle pressure is continued to be controlled at 500 p.s.i. by valves **80** and **86**.

Turbine synchronization and loading

As the heating is continued in the unit at constant pressure and flow, the steam entering the turbine through the turbine stop valve by-pass **94** warms the turbine parts which subsequently reach a state of equilibrium. The turbine is then synchronized and a load is applied and gradually increased to 5%, depending upon turbine design. This is accomplished by opening the turbine throttle stop valve by-pass **94** to full open position increasing the temperature and pressure of the flow entering the turbine. The turbine governor valves **100** are now wide open, and valve **80** may have closed depending on valve capacity. Prior to a further increase in turbine load, the turbine is placed on governor valve control by closing down on the governor valves until they assume control, and the throttle stop valve **96** is opened wide.

Turbine load is increased up to 30% by the gradual closing of valve **52** with a resulting rise in flash tank and throttle pressure to full load operating pressure (e.g., 3500 in a supercritical unit; 2500 in a subcritical unit) and increase in flow to the turbine. Firing rate is increased as necessary to obtain the required temperature at the throttle. Initially a 30% full load start-up flow had been established through the unit for cooling the furnace circuitry. At 30% turbine load, valve **52** is completely closed and the start-up system including the by-pass vapor lines are



conditions. A level in the primary superheater outlet header is readily established because of the hot condition of the unit with resulting high quality steam entering the primary superheater outlet header (flash tank). As soon as a level is established, valve **48** is opened. The subsequent pressure rise at the inlet to the high pressure turbine opens the turbine by-pass valve **80** to pass fluid from the finishing superheater to the condenser and control turbine throttle pressure at 500 p.s.i.

When the steam conditions leaving the finishing superheater match the turbine inlet parts, steam is admitted to the turbine for initial rolling. This is accomplished by opening the turbine stop valve by-pass control valve **94** and closing the by-pass valve **80**. The pressure at the turbine inlet is about 50 p.s.i. by virtue of the reduction in pressure through the by-pass control valve **94** or set initially for the hot re-start at higher pressures corresponding to the turbine capacity for the hot turbine conditions. This is readily accomplished with the present invention since the flash tank pressure (and consequently the turbine pressure) can be varied with load as required by the particular hot turbine conditions.

The turbine is synchronized and 15% load is applied immediately with valves **80**, **86**, and **52** sequentially closed to control flow to the turbine at the desired pressure. The closing of valve **52** gradually increases the load to 30%, and the throttle pressure to 3500, at which point valve **52** is completely closed removing the start-up system from service. During this operation the firing rate is increased to obtain the required temperature at the throttle.

At full pressure, valve **102** is completely open removing the pressure reducing station from service. This valve begins to open when the throttle pressure is near 3000 to further increase the throttle pressure. Loading above 30% proceeds by automatic combustion control regulation as in the cold start.

The controls

The controls for the system of FIG. 1 will now be described. It is to be understood that these controls, primarily for descriptive purposes, are not the sole manner of controlling the present invention. In the cold start-up sequence, the feed pump (**32**, FIG. 1) is on flow control to hold the minimum flow (for instance, 30% of full load flow). This is in response to a signal **110** from flow orifice **112** acting through controller **114** and signal **116**. The pressure reducing valve **42** is on pressure control (signal **118**) to hold the set point pressure upstream of the valve. The flash tank sub-loop valves and other start-up system valves are set as described in the foregoing description on the cold start-up sequence, holding the desired turbine throttle and/or flash tank pressure. With the pressure reducing station in service, the superheater outlet pressure will follow the turbine throttle pressure set point, subject to the pressure drop therebetween. The metered fuel and air control **120** for the burners **92** (the fuel and air input) is initially on manual adjustment (item **122** and signal **124**).

When turbine rolling and warming steam is available from the flash tank, the main flow line valve **48** is slowly opened, admitting steam to the finishing superheater and main steam pipes between the superheater and turbine. The resulting rise in throttle steam pressure to 500 p.s.i. opens turbine by-pass valve **80** (if valve **80** is wide open and the pressure higher than 500 p.s.i., valve **86** in steam dump line **84** opens as necessary to hold the 500 p.s.i. pressure). With the flow through the finishing superheater now held constant and equal to the flow through valve **80**, the firing rate is adjusted to achieve the desired steam temperature. When the desired steam conditions of temperature and pressure are attained, turbine stop valve by-pass valve **94** is slowly opened admitting 2–3% flow to the high pressure turbine. Throttle steam conditions are held constant by the simultaneous closing of the turbine by-pass valve **80** which results in a pound for pound transfer of the fluid from valve **80** to valve **94**.

The turbine parts then reach a state of equilibrium, and the turbine is synchronized and loaded up to, for example, 5% of full load. This is accomplished by fully closing the turbine by-pass valve **80** and closing as necessary valve **86**. The full flow through the finishing superheater, for instance a 5% flow, is fed to the turbine through the turbine throttle stop valve by-pass **94**. Since the by-pass control valve **80** is no longer available for pressure control, the pressure at the finishing superheater outlet is controlled and held at a set point by means of control valve **86**. At this stage only about 5% of the 30% minimum start-up flow is passed through the finishing superheater to the turbine, the remainder being disposed of in the flash tank by-pass sub-loops.

During this period of loading to 5%, although the fuel firing rate and air input responds primarily to manual control **122**, it will adjust for feed and main steam temperature to a limited extent. For instance, fed to temperature controller **126**, a main steam temperature signal **128** below the set point will increase the firing rate (signal **130**), whereas above the set point, it will decrease the firing rate. The feed water temperature (signal **134**) also is compared to the main steam temperature (signal **130**). This combined signal then modifies the manual control signal (**122–124**) for control of the fuel and air supply. The purpose of the feed water temperature signal is, that when the by-pass system is used, with flow to the high pressure heaters (for heat recovery and to aid raising the steam to turbine temperature), the feed water takes an initial jump in temperature. This is compensated for by reducing the fuel and air input.

At a 5% load and above, for example, control of the fuel and air input can be changed from manual to automatic by providing, for automatic control, a load demand signal **136**, for instance a 5% demand signal which represents the load applied to the turbine. A load signal **139** is provided as load demand signal **136** is compared with throttle pressure (**140**). The load signal **139** is then modified in a true control sense with the main steam temperature signal **130** and feed temperature signal **134**, as described above, the resultant signal controlling the fuel and air input.

Prior to a further increase in turbine load, throttle pressure control is shifted from control valve **86** to the governor valves by closing down on the wide open governor valves until they assume control; the throttle stop valve is opened wide. To achieve a load increase above 5%, the throttle pressure set point is gradually adjusted to full load pressure of 3550 p.s.i. from 500 p.s.i., increasing the turbine load to about 30% by the closing of valve **52**. At 30% flow valve **52** is completely closed, the flash tank start-up system being removed from service, no longer required for handling an excess flow. In this 5% to 30% load range, the temperature compensated load signal controls the firing rate.

Following removal of the start-up system from service, the feed pump **32** responds also to the load demand signal, and the heat input, flow rate, and pressure increase, programmed in a suitable manner with the load signal **139** and temperature signal **130**. The pressure reducing valves **42** under pressure control **118** open (and remain open) in an attempt to control the rising pressure associated with the increased flow above 30%.

FIG. 5 shows the flash tank header **20** containing a heat exchanger **141** disposed in the separated liquid portion **142** of the header. The header-heat exchanger may be incorporated into the system of FIG. 1 being of full pressure design. During start-up feed water passing through coil inlet line **143** via valve **144** is heated by the separated water in the header exiting through line **145** via valve **146** to the high pressure heaters. Coil by-pass valve **147** is closed during this time. This permits pre-

warming of the feed water during early start-up. With the heat exchanger **141** in the header **20** one high pressure heater and connections thereto may be eliminated as the heat exchanger **141** provides feedwater heating. A pressure vessel is eliminated since the header vessel is utilized to house the heat exchanger **141**. When heat exchanger **141** is no longer required, valve **147** is ramped open (from a load signal or feedback from the turbine governor valve position, not shown) and isolation valves **144** and **146** are closed. During normal operation at loads above 30%, the header-heat exchanger may be used for steam temperature control, that is, regulation of valves **144**, **146**, and **147** upon response to the temperature entering or leaving the finishing superheater (not shown) would admit sufficient feedwater through the heat exchanger to change the temperature leaving the finishing superheater.

The invention is also useful for low load operation. At turbine loads under 30% the by-pass system can be controlled to hold any circuit condition discussed herein. In addition, the pressure at the flash tank and turbine can be adjusted and maintained at any desired level for any low load condition.

Although the invention has been described with respect to specific embodiments, many other variations within the spirit and scope in the invention as defined in the following claims will be apparent to those skilled in the art.

What is claimed is:

1. A supercritical once-through vapor generator including

a working fluid circuitry comprising a main flow path and bypass means operatively connected to the main flow path, the main flow path including a vapor generating section and primary and secondary superheating sections connected in this series flow sequence;

an enlarged horizontal header means for one of said superheating sections, the tubes of said one superheating section being connected directly to said enlarged header means;

vapor-liquid separation means disposed within said header means in direct fluid flow communication with the tubes of said one superheating section whereby the flow into the header means is separable into a liquid stream and a vapor stream in said separation means;

said header means defining a liquid space and a vapor space receiving said liquid and vapor streams respectively from said separation means;

the bypass means including flow conduits in fluid flow communication with the header means liquid and vapor spaces;

pressure reducing valve means in said main flow path upstream of said header means to maintain full load pressure in said vapor generating section and to reduce the pressure of the working fluid entering said header means during start-up; and

flow conduit means bypassing said pressure reducing means so that the latter is in the main flow path only during start-up of the vapor generator.

2. A vapor generator according to claim **1** wherein said header means containing the separator means is horizontally oriented, the separating means comprising horizontal separators.

3. A vapor generator according to claim **1** wherein said header means containing the separator means is horizontally oriented comprising vertically extending pressure vessel portions, the separating means being disposed in said portions and comprising vertical separators.

4. A vapor generator according to claim **1** wherein said vapor-liquid separation means has an inlet portion and vapor and liquid outlet portions;

conduit means connected with said inlet portion and in flow communication with the main flow path downstream of said separation means; and

valve means in said conduit means so that said vapor-liquid separation means is operable only during start-up of the vapor generator.

5. A vapor generator according to claim **1** wherein said horizontal header means is the outlet header for said primary superheating section, the pressure reducing valve means being in said main flow path upstream of said primary superheating section.

6. A vapor generator according to claim **1** further including at least one bank of tubes disposed in said header means in said liquid space thereof;

input means for feeding the working fluid to said vapor generator; and

means communicating said input means with said bank of tubes for preheating the feed liquid flowing to the vapor generator during start-up.

References Cited

UNITED STATES PATENTS

2,989,038	6/1961	Schwarz	122—406
3,175,367	3/1965	Gorzegno et al.	122—406
3,183,896	5/1965	Lytle et al.	122—406
3,194,217	7/1965	Grabowski	122—406
3,220,193	11/1965	Strohmeyer	122—406
3,259,111	7/1966	Koch	122—406

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