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REACTORS—POWER

UNITED STATES ATOMIC ENERGY COMMISSION

A REPORT ON THE INTERACTION OF THE NUCLEAR AND POWER PLANT CONTROLS FOR THE SRE STEAM ELECTRIC GENERATING STATION

April 30, 1956

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I. INTRODUCTION

A previous Memo* describes the addition of the steam-electric generating facilities to the Sodium Reactor Experiment. That Memo describes the components of the station and studies the hazards involved. It was concluded that the addition of the steam plant would not significantly affect the safety of the SRE.

The purpose of this report is to describe in further detail the control systems that interconnect the SRE with the steam plant. The operation of these control systems under both normal and abnormal operating conditions is considered.

It is our opinion that the control systems included provide adequate operating control of the plant, warning of abnormal conditions, and provide for safe shutdown at times of serious operating problems.

II. DESCRIPTION OF CONTROL SYSTEMS

A. REACTOR CONTROLS

The reactor control system is composed of many parts, not all of which are of interest in this discussion. The following sections describe the controls principally concerned with the operation of the combined reactor and steam plant.

1. Control Rods - The reactor contains four control rods, two operate as shim rods only, and two as regulating rods. The shim rods may be operated singly or as a group at 0.3 ft/min from momentary contact hand control switches at the reactor console. The regulating rods may be operated at either 0.3 or 3.0 ft/min. At the higher speed, travel is limited to ± 6 inches. Only one regulating rod is used for the regulating function at a given time; the other is used as a third shim rod. The regulating rod may be operated from a momentary contact hand control switch at the console, or it may be operated by an automatic flux controller. During much of the time, the operator will have the rods on hand control; the automatic flux controller is principally for long, steady-state runs.

* NAA-SR-MEMO-1447, July 30, 1955.

2. Coolant - (See Fig. 1.) Sodium coolant is circulated by motor driven pumps, one in the main primary, and one in the main secondary coolant loop. The motor drivers are dc; each drive receives its power from a separate variable-voltage motor-generator set. The voltage of the generator and, therefore, the speed of the pump motor, is controlled from the reactor console by means of hand-operated switches that adjust the generator field. The primary and secondary pumps may be controlled separately, or "slaved" together. Under the latter condition, automatic controls will adjust the speed of the secondary pump as necessary to keep the ratio of secondary speed to primary speed a constant. Means for adjusting this ratio are provided. The control of the primary pump is manual at all times. The design calls for two rates of flow change - a slow rate of 5 per cent per minute, and a fast rate of about 30 per cent per minute.

The time required to transport sodium through the various parts of the system is appreciable. Figure 2 shows a schematic of the system, with the transport delays tabulated for full flow.

The auxiliary sodium loop of the reactor is unaffected and unchanged by the addition of the steam generation facilities. The auxiliary loop will be in operation at all times. In case of power outage, the pumps in the loop are operated from an emergency power supply.

3. Safety - The reactor has three levels of safety action: the alarm, which informs the operator of abnormal conditions; the setback, which motorizes the control rods in, and requires operator action under standing instructions; and the scram, which automatically drops the safety rods and cuts off the main sodium pumps. The scram loop is a series arrangement of relay contacts that are closed when conditions are normal. Any abnormal condition, or loss of voltage, breaks the loop and scrams the reactor. The present list of scram conditions includes the following: (1) high fuel channel sodium exit temperature (any two of three), (2) short period, (3) high flux, (4) low coolant flow in either main loop, (5) high temperature in cold leg of main primary or secondary loop, (6) loss of main airblast exchanger fans (bypassed when operating with the steam generator), (7) electric power failure, (8) earthquake, (9) manual. To this will be added one scram from the steam plant, as described in subsequent paragraphs.

Setback alarms of interest here are as follows: (1) above-normal flux, (2) short period, and (3) above normal fuel channel sodium exit temperature.

All of the above scrams and setbacks (except loss of power, and earthquake) are preceded by ordinary alarms at lesser abnormal values. Many other alarms are included, but not listed here.

4. Operation - The reactor is normally operated by controlling sodium flow and control rod position to keep the fuel channel outlet temperature constant. For example, with the reactor in operation and temperatures established, an increase in power level may normally be accomplished as follows: (1) the operator sets the primary sodium pump control switch to increase speed at the slow rate of 5 per cent per minute; (2) the secondary pump automatically follows the primary pump; and (3) the operator controls the regulating rod by hand to hold fuel channel outlet temperature constant.

The faster pump rate of 30 per cent per minute may also be used in a similar manner. However, this rate will probably be reserved principally for minor trimming action, or for setbacks.

B. STEAM PLANT CONTROLS

The steam plant facilities of Southern California Edison will be operated from a control room separate from the reactor control room. All essential controls, recorders, pressure and temperature gages, alarms and associated annunciators for the steam plant will be located in the Edison control room.

The steam control system is designed to remove heat automatically from the secondary sodium loop as required in order to maintain a constant sodium temperature return to the intermediate heat exchanger. Thus, the steam plant follows the reactor, which is the inverse of standard power plant operation. The following description of controls has been restricted to those directly or indirectly affecting the secondary sodium loop as the remainder of the control system is typical of any small, conventional steam-electric generating station.

1. Feedwater - (See Fig. 3 and 4.) The principal control element of the steam plant, as far as connection with the reactor goes, is the feedwater control valve. With the turbine steam pressure regulator (see next paragraph) maintaining a constant backpressure, the rate of water flow through the steam generator determines the heat extracted from the sodium. As long as heat is removed

from the sodium, it is not of direct concern to reactor operation whether the steam produced is used in the turbine, dumped in the condenser, or dissipated to the atmosphere.

As shown in Fig. 4, a quick-response, resistance-type temperature device (RTD) in the boiler outlet sodium line transmits a signal to Recorder-Transmitter M3C and the "Standatrol" relay. The output of the Standatrol, which includes proportional plus reset action, controls the feedwater valve. Since there is appreciable lag in the steam generator itself, and a two second time constant in the RTD, a signal from sodium flow has been added as an anticipatory device. This signal, derived from the main secondary flowmeter, programs the feedwater valve in accordance with sodium flow. The temperature controller maintains final control, however, and will return the sodium temperature to its set point when it drifts off. The feedwater flow control valve is equipped with an air lock so that the valve will maintain its set position in the event of control air failure.

2. Steam Pressure - (See Fig. 3.) During normal operation the main steam pressure will be maintained at 600 psig by an initial pressure regulator supplied by the turbine manufacturer. As the main steam header pressure increases or decreases with reactor output, the turbine control valves will automatically open or close to maintain the steam pressure constant. In this manner, the electrical load on the turbo-generator will vary with steam generator output, and therefore with reactor power.

For starting and shutdown purposes, a main steam by-pass has been provided for routing excess (up to 4 Mw thermal) steam to the condenser. During the starting period, the main steam header pressure is controlled by Pressure Control Valve VPC-9. After a steam flow of 7000 to 8000 pounds per hour at 600 psig has been stabilized, steam will be admitted to the turbine for rolling, bringing up to speed and initial loading of the unit. As steam is admitted to the turbine, Control Valve VPC-9 will maintain 600 psig header pressure by slowly closing until all the available steam is flowing to the turbine. At this point, the by-pass system will be isolated by closing Valve MOV-3; simultaneously, the initial pressure regulator will be placed in service by opening Valve 95.

3. Steam Temperature - (See Fig. 3.) The steam turbine is designed for a maximum working temperature of 825° F. This steam temperature limit will

be maintained automatically by regulating the flow of water to a spray type attemperator through Valve VTC-2.

4. Electrical - (See Fig. 5.)

a. Generator, Transformer and Transmission Line - The generator is a completely enclosed outdoor-type unit with a capability of 7500 kva at 100 per cent power factor. Generation is at 4160 volts which is stepped up to 66,000 volts by a 7500-kva transformer. The transformer is connected to the generator bus through a 4160-volt generator air-circuit breaker and to the Edison system by a transmission line to a 66-kv circuit breaker located at Chatsworth Substation, approximately 600 yards from the steam station.

Protection of the generator and transformer is provided by means of differential and overcurrent relays which will trip the 66-kv oil-circuit breaker at Chatsworth Substation and the 4160-volt generator breaker in event of a fault within the generator, generator bus, or the transformer.

Protection of the 66-kv oil-circuit breaker at Chatsworth Substation and the 66-kv transmission line is provided by overcurrent relays at Chatsworth Substation or by the generator overcurrent relays. Lightning arrestors are provided for surge protection of the transmission line and the 66-kv transformer.

Protection against generator instability due to momentary system disturbances is provided by a relay that will trip only the 4160-volt generator breaker.

Controls for the generator, the 4160-volt generator breaker and the 66-kv breaker at Chatsworth Substation are located on the steam plant control board.

b. 480-Volt Auxiliary Equipment - Auxiliary power is provided by a 750-kva auxiliary transformer connected to the 4160-volt bus and to 480-volt switchgear which is used to control the major auxiliary equipment.

Protection of the 480-volt switchgear is provided by overcurrent relays which will trip the 66-kv breaker at Chatsworth Substation and the 4160-volt generator breaker.

Provision is made for maintaining auxiliary power from the generator following a system disturbance that may cause a loss of power from Chatsworth Substation.

Protection of all major auxiliary equipment served by the 480-volt switchgear is provided by overcurrent devices in the switchgear.

III. INTERCONNECTIONS BETWEEN REACTOR AND STEAM PLANT

A. CONTROL INTERCONNECTIONS

1. Scram Circuit - One signal from the Edison plant will be included in the SRE scram loop. This signal is from loss of feedwater pressure, derived from Low Pressure Switch-17 (see Fig. 3). Since low pressure also initiates startup of the standby boiler feedpump, the scram signal is fed through a timing relay set for about eight seconds. If the standby pump has not started and recovered pressure during this period, the reactor will be automatically scrammed. In the SRE control room, a switch will be installed to by-pass the Edison scram when operating the reactor independently of the steam generator by using the main air-blast exchanger to dissipate heat. This bypass switch will be appropriately interlocked so that an alarm is sounded if the scram is by-passed when it shoud be operative.

2. Sodium Flow Signal - A signal proportional to secondary sodium flow is included in the Edison feedwater control scheme, (Section II-B-1 and Fig. 4). This signal is derived from an extra set of electrodes on the main secondary SRE sodium flow meter.

B. INFORMATION INTERCONNECTIONS

The following Edison information will be displayed in the SRE control room.

1. Kilowatt output (indicating)
2. Steam pressure (indicating)
3. Feedwater flow (indicating)
4. Sodium temperature at outlet of steam generator. This is displayed on a recorder that has high and low alarm switch attachments.
5. Indicating lights showing position of sodium valves in the piping to the steam generator.
6. Alarm from low feedwater pressure (in conjunction with scram signal, Section III-A-1).
7. Alarm from high or low sodium temperature at outlet of steam generator (from recorder, List 4 above).

8. Alarm from turbine throttle valve trip.
9. Alarm from high or low pressure of monitoring fluid in the steam generator.

The following SRE information will be displayed in the Edison control room.

1. Neutron flux level (expressed only as per cent power)
2. Alarm from reactor scram
3. Alarm from reactor setback
4. Sodium temperatures at inlet and outlet of steam generator (from Edison's own measuring devices).

C. COMMUNICATION BETWEEN SRE AND EDISON AREAS

1. Talk-Back Speaker - One talk-back speaker will be installed in the Edison control room and connected to the master intercom station at the SRE console.

2. Battery-operated Telephones - A three-telephone battery-operated circuit will be installed, with phones located at the Edison control room, operating platform of the steam turbine, and SRE control room. Buzzer call devices will be included in the installation.

3. Extension Telephones - Both the SRE and Edison control rooms will have extension telephones from the main Santa Susana switchboard. One extension may be dialed from the other without calling the switchboard operator.

IV. OPERATIONAL PROBLEMS AFFECTING REMOVAL OF HEAT

The following Sections list operating problems, in the steam plant, that might affect the ability of the steam generator system to remove reactor heat. Possible occurrence of these events, and the means taken to counteract them, are discussed.

A. LOSS OF AUXILIARY POWER (See Fig. 5.)

The 480-volt electrical system supplying the pumps, compressors, and other electrical loads of the steam plant, is referred to as the auxiliary power system. Complete loss of this system enforces a shutdown of the steam generating plant. The principal effect on the reactor plant is the sudden loss of feedwater to the steam generator and, therefore, the loss of heat removal capacity. Loss of feedwater is discussed at length in subsequent Sections. The following conditions can cause loss of auxiliary power.

1. Bus fault on 480-volt or 4-kv busses. This is considered to be unlikely because of the construction and operating record of modern metal-clad switchgear. Ground detectors and alarms are provided to detect grounds, so that repair can be made before a fault develops.
2. Transformer failure, either main or auxiliary. Operating experience indicates that transformer faults are rare.
3. Generator failure or overload. Either internal failure of the generator or extreme overload will trip off the entire electrical system.
4. Transmission line failure between the steam plant and the main Edison substation, located 600 yards away. This is probably the most exposed part of the system, although its location away from any road eliminates the possibility of damage due to traffic.
5. Loss of power supply to the main Edison 66-kv substation. This is unlikely since the station is fed by two or more lines of high reliability. Should complete failure occur, the Edison generator with which we are concerned will shortly trip off due to overload. At the same time, since the SRE power supply is derived from the main Edison substation, the reactor will scram from its own loss of power.

B. LOSS OF FEEDWATER

The loss of feedwater is probably the single most serious event with this once-through steam generator. Because of the small volume of water, continued heat input after loss of water input will evaporate the remaining water quickly, thereby causing the cool portions of the steam generator to heat rapidly. From the standpoint of reactor operations, loss of boiler feedwater means imminent loss of heat removal capacity, thus imminent shutdown. Possible causes of loss of feedwater, and the steps taken to minimize the disturbance, are listed.

1. Loss of one Feedwater Pump - Two full capacity pumps are provided in the system, one of which is operating, and one on automatic standby. If the operating pump fails for any reason, the drop in pressure initiates Pressure Switch LPS-16, which in turn starts the standby pumps. It is estimated that, on

sudden loss of pressure, the automatic transfer will be accomplished in less than five seconds. This will be fast enough to prevent running the steam generator dry. During this brief period, the sodium outlet temperature will rise slightly, then return to normal when the standby pump recovers the feedwater flow. This pulse of slightly higher-temperature sodium will return to the SRE, reaching the secondary expansion tank in about 13 seconds (at full flow conditions). Since there will be approximately 50 cubic feet of 440° sodium in the tank, and perhaps 10 to 12 cubic feet of sodium (about five seconds flow at 12 ft/sec in a 6 inch pipe) involved in the pulse, the temperature of the sodium eventually reaching the reactor will be considerably less than the temperature rise at the steam generator because of the large heat capacity of the sodium in the expansion tank.

In the event that the second pump does not start, the timing device referred to in Section III-A, will run out in eight seconds (from the time low pressure was first recognized) and scram the reactor. The sodium outlet temperature from the steam generator will start to rise as the remaining water is boiled out. However, because the main sodium pumps were scrammed with the reactor safety rods, the sodium flow rapidly falls to its convection flow value, as shown in Fig. 6. It is estimated that the front of the temperature transient will not reach the secondary expansion tank until 20 seconds after the disturbance starts. Then the rate of flow through the expansion tank will be quite slow, perhaps as much as 100 seconds, depending on the mixing in the tank. It then takes perhaps another 40 to 60 seconds to reach the intermediate heat exchanger, then perhaps 30 seconds in the primary loop to reach the reactor inlet. This total time, then, is about three minutes before the temperature disturbance caused by loss of feedwater returns to the reactor core. Probably the disturbance caused by scram itself would be more significant, as far as temperatures in the core are concerned. Of course, all the components in the secondary loop will be subject to some thermal shock as the cold leg heats up. The steam generator will be the first to receive this, with the sodium return piping and secondary expansion tank following.

One conclusion reached from the above discussion is that the speed of operation of the automatic standby boiler feedpump system is determined primarily by the need to protect the steam generator from loss of water. While the steam generator is designed to operate at temperatures even above the 900° F presently contemplated, the sudden heating of the cool end of the steam generator will cause some thermal shock, most of which is expected to be absorbed in a loose-fitting thermal shield provided for this purpose.

From the reactor standpoint, the long transport delays make the timing of the scram much less critical. However, the time should be held to the minimum consistent with reliable operation.

2. Loss of both Feedwater Pumps - Mechanical failure of both pumps at the same time is unlikely. The most likely cause of such loss is loss of auxiliary power for the reasons discussed in this Section under A. As described in the previous paragraph, the reactor will scram in eight seconds. If the loss of power affects the entire Santa Susana area, the reactor will scram even sooner from its own power failure. In the event that the feedwater scram circuit should fail to operate, both the Edison and SRE operators would be warned by independent alarms from high sodium temperature at the steam generator outlet. Manual scram could then be initiated by the SRE operator.

3. Low Deaerator Level - (See Fig. 3.) Both boiler feed pumps receive suction from the deaerator. If the deaerator level drops to a dangerously low level, it will be necessary to shut off the feed pumps before damage to the pumps occurs. The normal deaerator level is controlled by Level Controller VLC-3. If the condensate pumps should fail (which is unlikely due to having duplicate pumps with an automatic standby system similar to that of the feed pumps) or the level control valve should stick in the closed position, the deaerator level will fall. An alarm will be given by means of LLS-4. There will then be about 500 gallons of water in the deaerator that can be used before LLS-5 will shut off the feed pumps. These 500 gallons are equivalent to four minutes steaming at full reactor load. Upon receiving the low level alarm, the Edison operator will check his instruments. If he can not correct the condition immediately, he will call the reactor operator and request a runback of the reactor. The reactor pumps will be set to reduce flow at a rate of 30 per cent of full flow per minute. At the end of three minutes, some 200 gallons of feedwater will have been used, leaving 300 gallons. Since the reactor is now down to 10 per cent power, this 300 gallons will last approximately 25 minutes. This permits either repair of the faulty condition or orderly shutdown of the reactor.

C. LOSS OF COOLING WATER

Loss of cooling water to the condenser will result in loss of vacuum. The Edison operator will trip the throttle manually if he can not restore vacuum immediately. In this case, steam will be blown to atmosphere until the condition is corrected or an orderly shutdown can be accomplished.

D. LOSS OF LOAD

The turbine throttle valve will be tripped under any of the following conditions:

1. Differential relay operation
2. Overload relay operation
3. Manual trip
4. Overspeed trip
5. Low lube oil pressure.

In cases 1 and 2, the auxiliary power will also be interrupted (as discussed in this Section under A). For the remaining conditions, the auxiliary power will not be interrupted. The steam generator can then continue to dissipate reactor heat by blowing steam to atmosphere, or by-passing steam to the condenser. Sufficient water is available to blow steam to atmosphere for an hour at full reactor power, or proportionately longer at lower loads.

E. STEAM GENERATOR FAILURE

In the event of a leak in either the water or sodium side of the steam generator tubes, the change in pressure registered by the mercury monitoring fluid will sound alarms in both the Edison and SRE control rooms. An orderly shutdown can then be made.

F. EQUIPMENT FAILURE

Shutdown of the steam plant due to equipment failure is unlikely, since all vital auxiliary components are provided in duplicate. There are two boiler feed pumps, two condensate pumps, two circulating water pumps, and two cooling tower fans. The steam-jet air ejectors are backed up by an electrically operated vacuum pump. The main shaft-driven turbine oil pump is backed up by an electrically operated pump. Automatic circuits are included to start the standby units in the event of trouble with the operating unit. Provision of equipment in duplicate also permits better maintenance, since a piece of equipment can be taken out of service briefly for routine maintenance without shutdown of the plant.

In the event of equipment failure, or equipment misoperation, appropriate alarms will alert the operators to prevent further trouble. Steam plant problems not directly involving heat removal ability can be handled directly by the Edison operator. If heat removal ability is involved, the SRE operator will receive a high or low temperature alarm from a thermocouple immediately adjacent to the steam generator outlet. If this alarm fails, or if either operator takes no action, the SRE operator will again receive an alarm some 30 to 40 seconds later from another thermocouple located near the intermediate heat exchanger. If the temperature is rising, indicating loss of heat removal ability, continued deviation will result in automatic scram.

V. OPERATIONAL PROBLEMS NOT AFFECTING REMOVAL OF HEAT

A. LOSS OF CONTROL AIR PRESSURE

The selection and installation of air-operated equipment is such that loss of control air results in the control valves staying in a "status quo" condition, or going full travel to the safest operating condition. As an example of the first, the automatically-operated feedwater control valve will remain at its last set position if the control air fails. As an example of the second case, Valve VLC-3 in the feedwater supply to the deaerator, and Valve VLC-4 in the deaerator high level dump line, both will open in the event of control air failure. This action prevents loss of feedwater from air failure. Two air compressors are provided - one for "control" air and one for "service" air. In the event of loss of the control air compressor, backup is provided by the service air compressor.

Alarms are provided to warn the Edison operator of loss of air pressure. If such an event occurs, the plant will remain in operation on manual control. The Edison operator can then alert the reactor operator of this fact. The two plants can then be held in steady state operation while repairs are made, or shut down in orderly fashion at the discretion of the operators.

B. LOSS OF CONTROL ELECTRICAL POWER

Control power in the steam plant is taken from a 125 volt, 120 ampere-hour battery system of highest reliability. All components are arranged to fail safe. Automatic battery-charging equipment is provided. The control systems of the Edison and SRE areas are not directly connected; any interconnections are through suitable isolating relays. Therefore, a fault or failure in one system will not affect the other.

VI. RESPONSE OF STEAM PLANT TO REACTOR OPERATIONAL PROBLEMS

A. SCRAM

If the reactor scrams from its own operating difficulties, the problem of the steam plant is to back down smoothly as the heat input from the reactor falls off. Since for most scram conditions the temperatures seen by the steam generator will not change rapidly (due to the large amount of sodium in the reactor plenum), the immediate control problem is to match feedwater flow and power generation to heat input as the sodium flow falls off rapidly. In response to large changes in the sodium flow signal, the feedwater valve is capable of going from full open to full closed in about 6 to 8 seconds (see Fig. 4, Bailey Instrument Control Diagram). This is expected to be sufficiently fast to match the decline in sodium flow after scram as shown in Fig. 6. At the same time, the initial pressure regulator of the turbine will close the control valves to the turbine as the steam pressure falls off. The Edison operator will then open the steam bypass valve to the condenser, and remove the turbine from service. The flow of feedwater remains under automatic control with return sodium temperature resetting the feedwater valve as necessary. The pressure in the steam generator is then under the control of PIC-8 (Fig. 3) which controls the rate of flow of steam through the bypass to the condenser. The steam plant can continue to dissipate heat, controlling the feedwater rate so that sodium returned to the reactor remains at or near 440° F as long as necessary. An alarm has been provided in the Edison control room to alert the operator immediately in the event of reactor scram.

B. SETBACK

In the event of reactor setback, the operation is similar to that described above for scram, although the rates are much slower.

C. REACTOR TRANSIENTS

Reactor transients involving sodium flow will be met as described in the paragraph on scram. The anticipation signal from sodium flow will provide rapid response.

Reactor transients involving temperature are not expected to be severe, because of the large volume of sodium in the upper plenum of the reactor. However, any transient temperatures in the hot leg of the secondary loop must be accepted by the steam generator. The use of a high speed resistance-type temperature detecting element (time constant of two seconds) on the sodium outlet temperature controller will prevent the outlet sodium temperature from getting too far from its set point.

VII. PREOPERATIONAL TESTS

The steam generator controls, and all interconnections with SRE, will be thoroughly tested before operation. All automatic transfer schemes will be tested for timing and reliability. The interaction of sodium flow and feedwater flow instruments and controls will be verified by actual flow tests before the reactor is put into power operation.

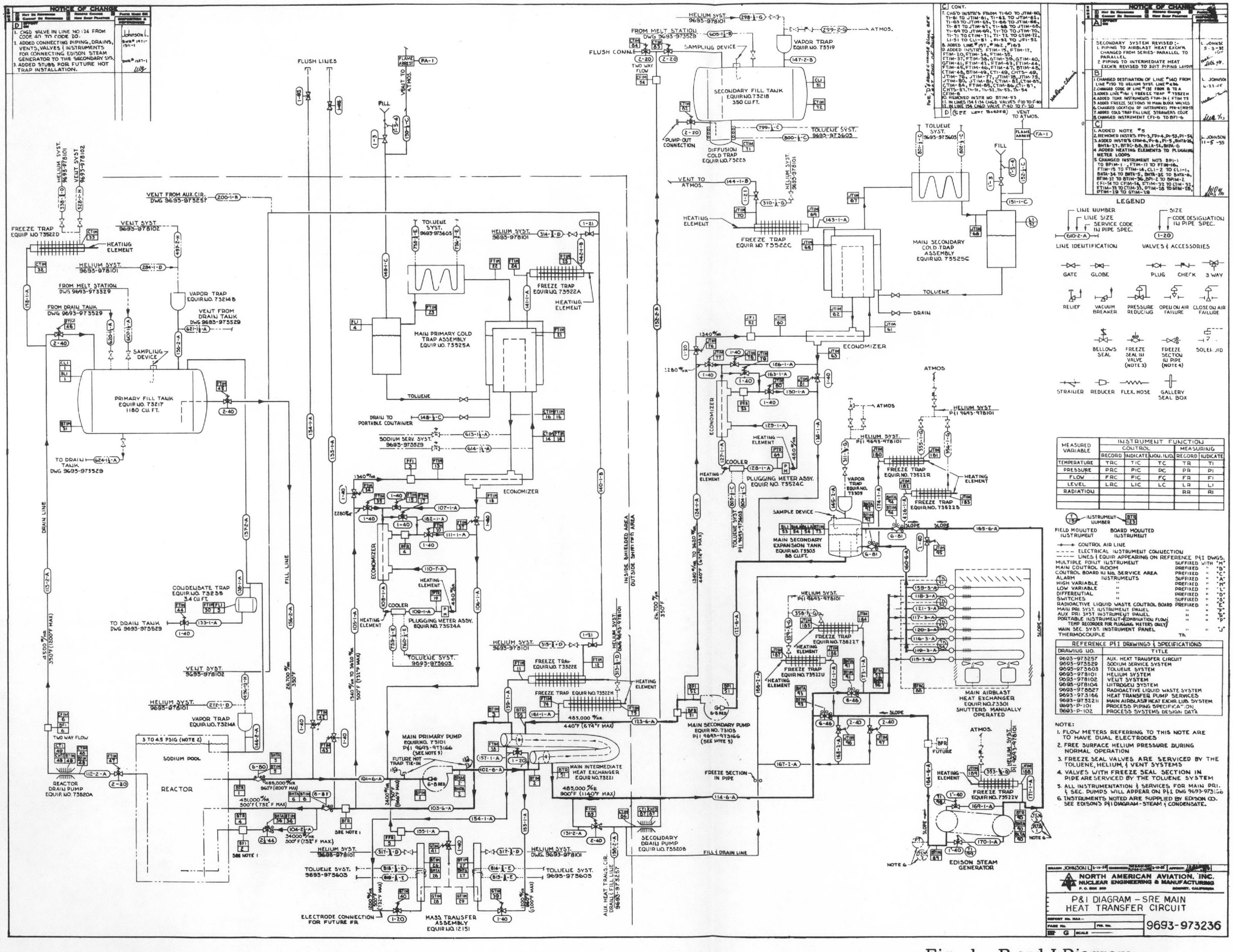

Fig. 1. P and I Diagram - - Reactor

Run	Length (nearest ft)	Full Flow Velocity, ft/sec	Full Flow Transport time, sec
A-B	70	13.1	5.3
B-C	21	3.8	5.5
C-D	79	12.1	6.5
E-F	61	12.9	4.7
F-G	192	12.9	14.9
G-H	76	1.9	39.5
H-I	166	12.0	13.8
I -J	4	0.2	20.0*
J -K	104	12.0	8.7
K-E	21	0.9	23.3
E -F'	58	12.9	4.5
F'-G'	48	13.3	3.6
G'-H'	48	5.5	8.7
H'-I'	42	12.6	3.3

*Depends on Mixing in the Tank

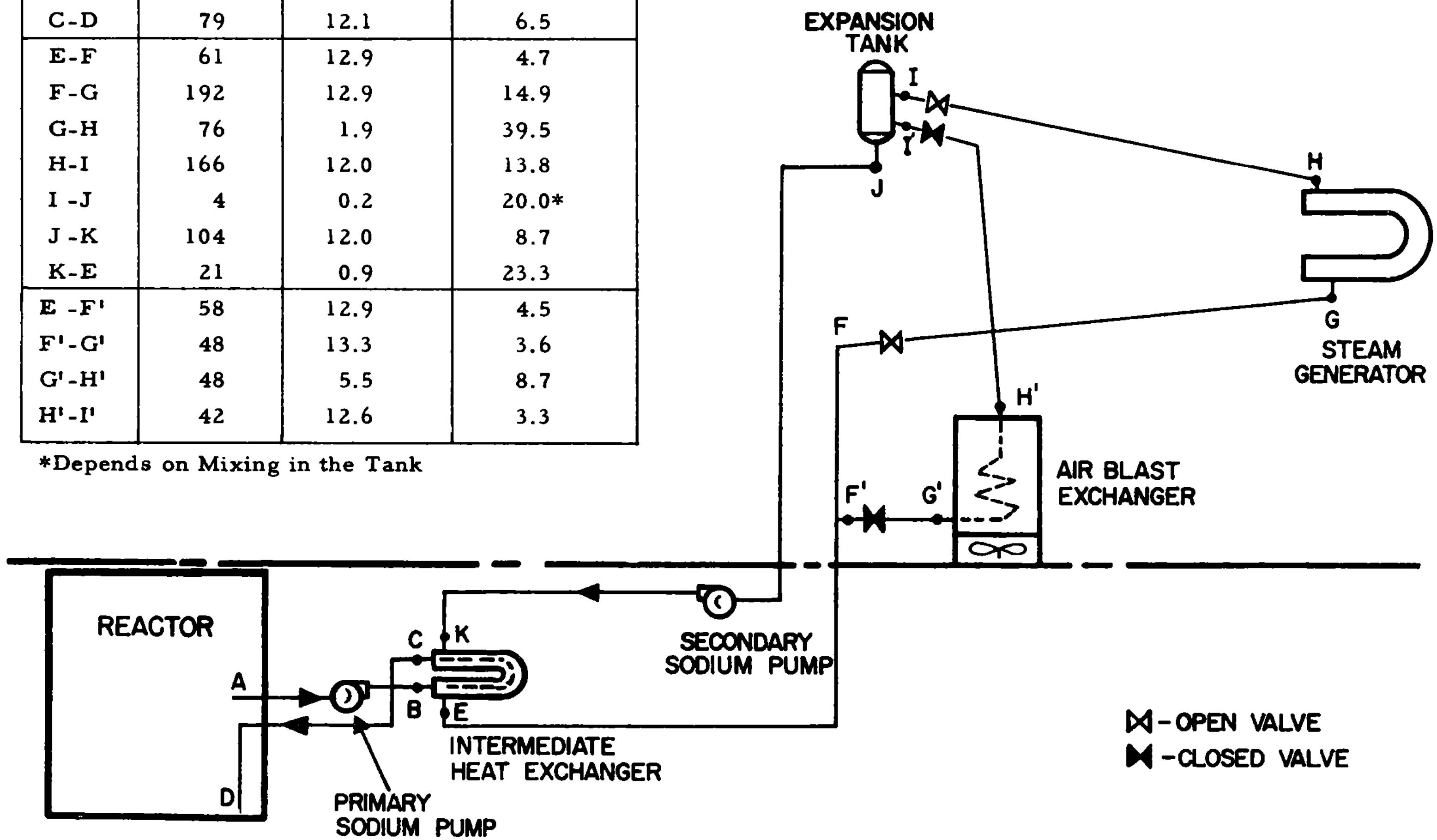

Fig. 2. Transport Delays

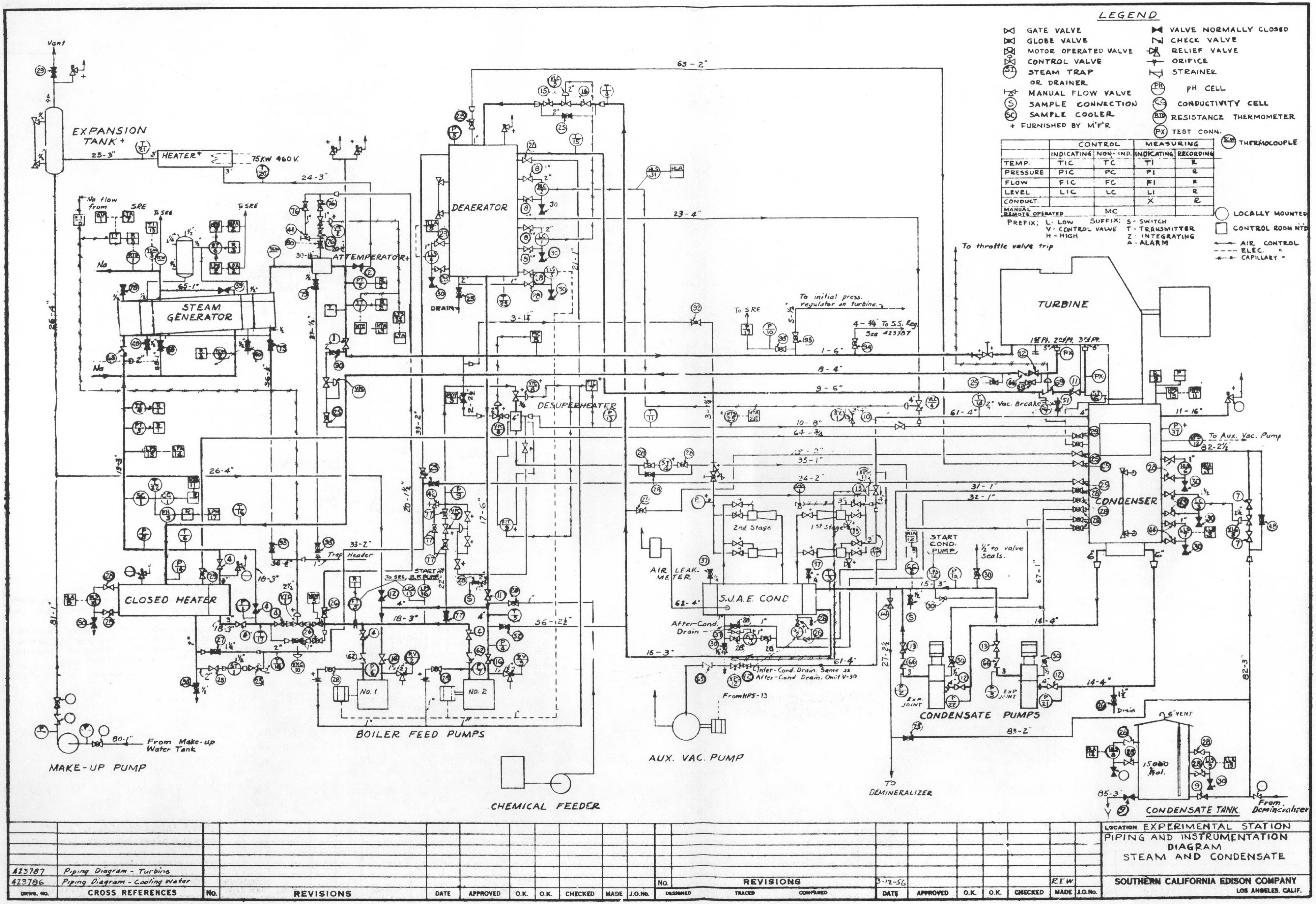

Fig. 3. P and I Diagram - - Steam Plant

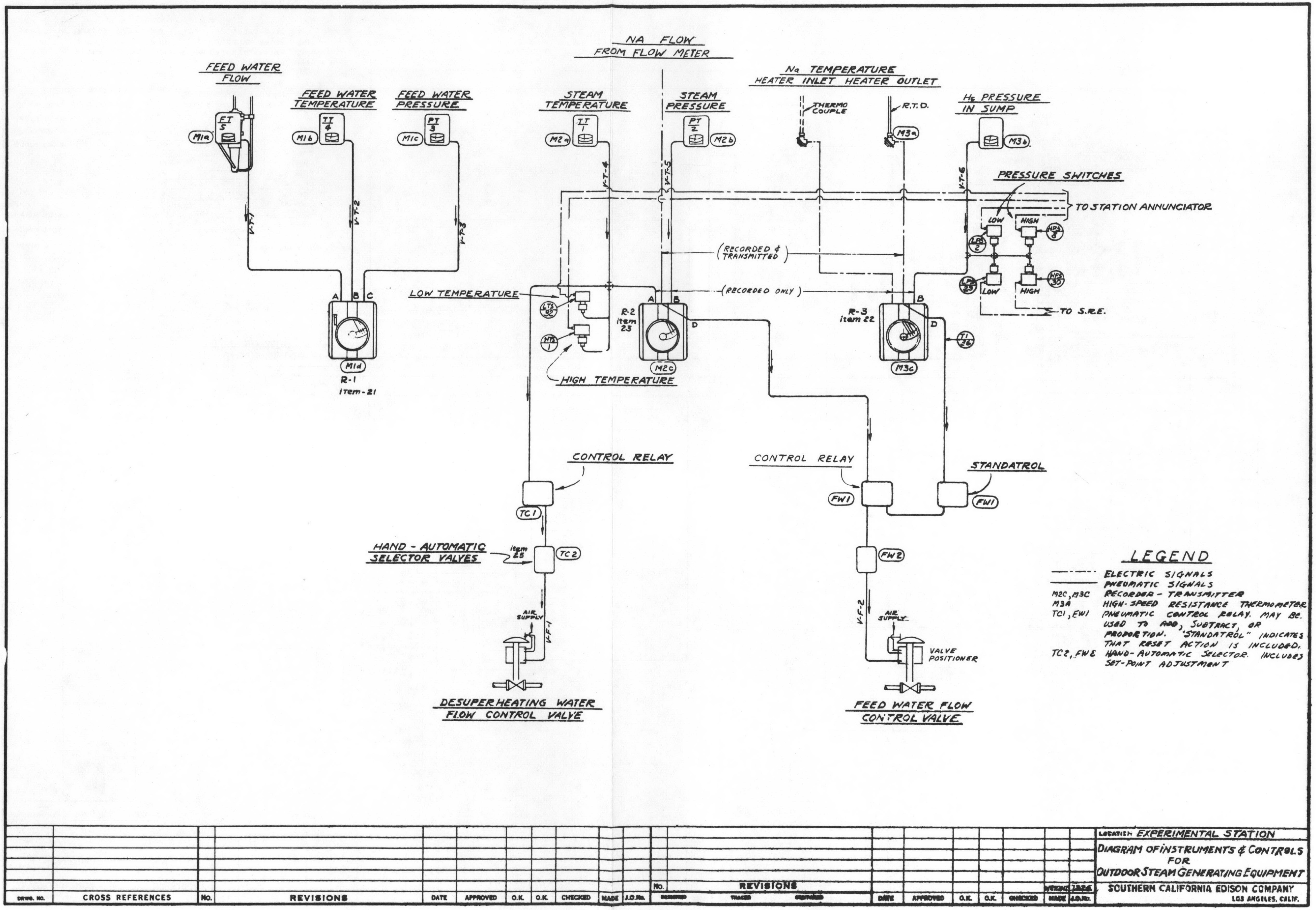

Fig. 4. Instrument and Controls Diagram - - Steam Plant

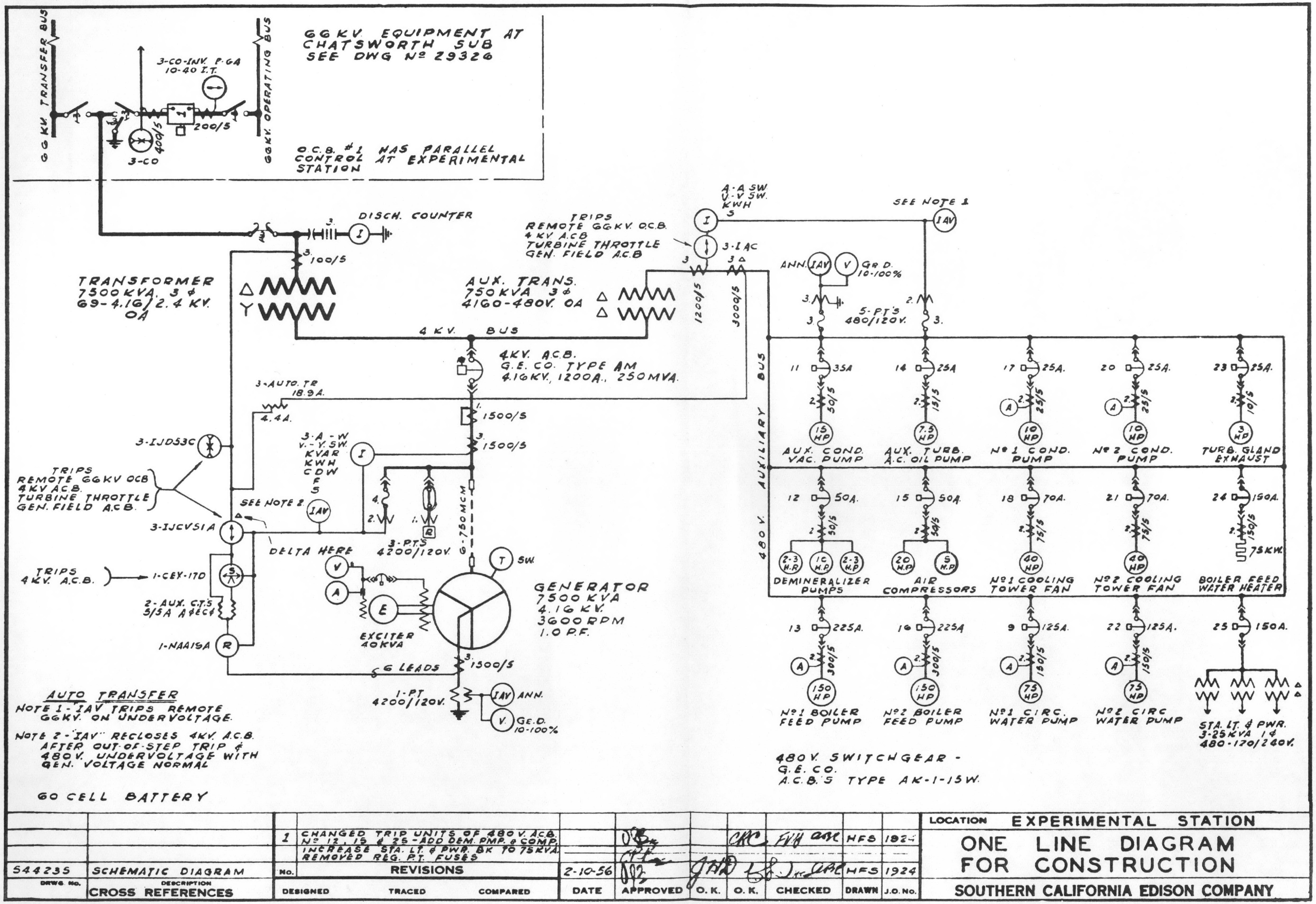

Fig. 5. Electrical Single-line Diagram - - Steam Plant

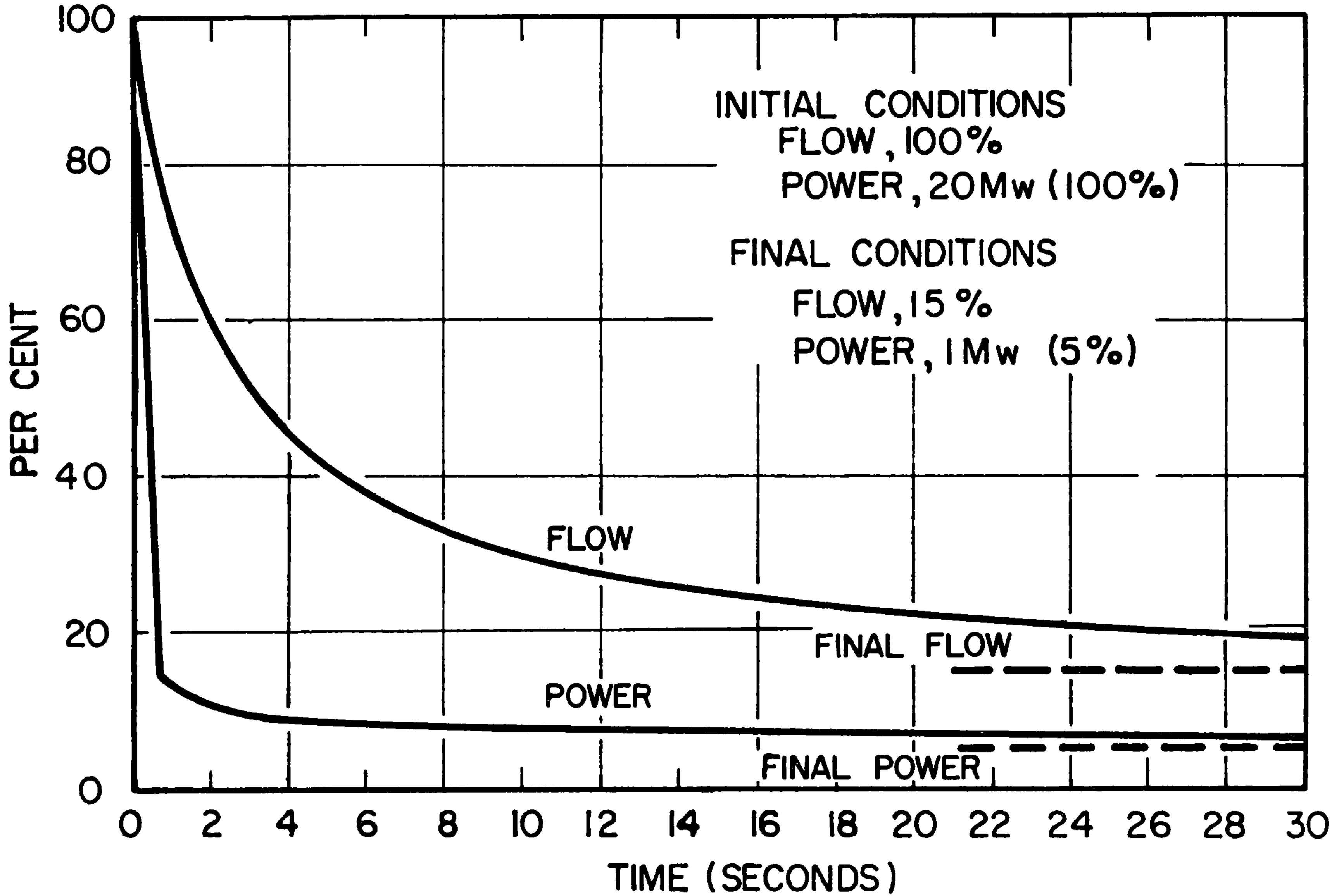

Fig. 6. Flow Decay Curves