

## OPERATION

The following outlines a method of starting and putting the combined non-condensing, superposed, and feed-heating turbine into service, in which advantage is taken of the fact that in this particular case there is no steam bypass around the turbine and, therefore, the boiler and the turbine can be brought up together. Under the circumstances, it is possible to heat the turbine gradually during the start and, by combining the operation of starting the boiler and turbine, it is possible to avoid unnecessary waste of steam, boiler feed water, and time.

An alternative scheme for starting with full throttle steam pressure is also given, as such a condition may arise although it will be only under some unusual plant condition, and the method of starting the boiler and turbine together is preferred.

The main turbine is designed for steam at 1200 lb. g. 900°F. at full load, exhausting at 200 lb. g. into the station header and to the feed-heating turbine. A 200 lb. g. exhaust pressure regulator has been supplied with the turbine, designed to control the main governor position to pass the necessary steam to maintain exhaust pressure. This device introduces important complications when supplying exhaust steam to a header system which also receives steam from boilers having their own automatic regulators. We now understand that it is the plan in this case to use the 200 lb. exhaust regulator only as a pressure limiting device, which means it will be adjusted for a pressure above that normally held by the old boilers and the regulator will then be inoperative except in an emergency.

The feed heating turbine receives steam from the 200 lb. g. main turbine exhaust, and in turn exhausts into a deaerating heater at 5 lb. g. and bleeds non-automatically to an intermediate feed heater where the pressure reaches 60 lb. g. at full load. Steam to the feed heating turbine is controlled by a speed responsive governor which, however, is also controlled by a 5 lb. g. pressure regulator connected to its exhaust.

The main throttle valve is a combination of single-seated, unbalanced valves opening in series. The position of the hydraulic operating piston is determined by shifting a relay controlled by the hand wheel mounted on the throttle valve floor stand. As the operating piston rises, it first lifts a small pilot and then picks up the inner, or bypass, steam valve which has about 10% of the area of the main throttle valve and can, therefore, be lifted against a steam pressure difference ten times as great as can the main valve. The maximum available lifting force is determined by the maximum oil pressure that can be established below the valve operating piston with the auxiliary oil pump in service. This will be about 75 lb. on a 23 in. diameter piston and will lift the main valve against a maximum of about 150 lb/in<sup>2</sup> pressure difference, or the bypass valve against about 1500 lb/in<sup>2</sup> difference.

When the bypass valve has lifted a short distance, it picks up the main valve but the design proportions are such that when starting up with full steam pressure at the throttle, the turbine will be brought to speed and under governor control before the main valve opens. In the normal manner of starting up a turbine, the governor valves are initially wide open, but as operating speed is reached they will close and the pressure across the throttle valve becomes practically equalized, so that the main valve is normally lifted when there is practically no unbalance.

The bypass valve will not pass sufficient steam to bring the turbine to speed in case the throttle steam pressure is far below normal; therefore, to start with reduced throttle pressure, as is planned in this case, it is necessary to arrange to partly close the governor valves at low speed in order to open the main throttle valve fully.

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The governor on the main turbine, as well as that on the feed heating turbine, is equipped with a manually controlled valve to permit building up an oil pressure on the governor operating relay and close the inlet valves at any desired speed. On the feed heating turbine governor this valve is of the needle type, built into the governor housing since accurate adjustment of this governor at intermediate positions is not required. On the main turbine this valve is external to the governor and is a high grade spring loaded oil pressure regulating valve. The pressure held by this valve is easily adjusted by setting the spring loading for a value corresponding to any desired governor position at any speed. This valve is described in detail in I.B. Leaflet 6337.

In addition, each governor has a wide range speed changer so that normal speed responsive control may be obtained from about two-thirds to full speed. The speed changer on the main turbine governor can be adjusted either manually or by remote electrical control. The feed heating turbine governor has only manual control of its speed changer.

A turning gear is provided for revolving the rotors during shut-down periods. It should be used continuously during short shutdowns and for a sufficient time after shutting down for long periods to permit the turbine to cool to approximately 300°F. The turning gear may be stopped for a few minutes only, if necessary, after short rolling periods, but continuous rolling is preferred. A motor driven oil pump is provided for lubrication during rolling periods. The turning gear should always be used for a sufficient time before starting to insure the turbine rotors being straight.

### STARTING TURBINE AND BOILER TOGETHER

Prior to starting in the following manner, it is assumed that:

- (a) The turning gear with its motor driven lubricating pump is in service.
- (b) The ventilating steam line between the turbine cylinder and the inlet side of the throttle valve is closed.
- (c) The motor driven oil pump supplying the hydrogen shaft seals is in operation and the generator casing is charged with hydrogen. Complete instructions covering the operation and control of the hydrogen cooling system is given in I.B. 5878-A.
- (d) The boiler has been started and steam pressure has been built up to 100 - 125 lb. g. at the turbine throttle.

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- (1) Start the steam driven auxiliary oil pump and see that it is under proper control of its pressure regulator which operates from the bearing oil pressure. When the steam driven auxiliary oil pump establishes pressure in the system, both turbine governors should open wide.
  - (2) Shut down the motor driven oil pump which has been furnishing lubrication while operating on the turning gear.
  - (3) Open all cylinder and steam header drains, making sure that the steam header is free of water. These drains are to be closed later on after having established reasonable steam flow and pressure in the turbine and having evidence that there is no further condensation.

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- (4) Open the 8 in. manually controlled atmospheric exhaust line from the feed heating turbine.
- (5) Open the gate valve in the 200 lb. exhaust line and also the valve in the steam line to the 60 lb. feed heater. (Both of these lines are protected against reverse flow of steam by check valves.)
- (6) Check that the hydraulic closing piston on the 200 lb. check valve is in position to permit this valve to open when the turbine exhaust pressure has been built up. In order to establish pressure in the overspeed tripping system and to permit this check valve closing mechanism to assume the position corresponding to open valve, it will be necessary to engage, but not lift, the throttle operating mechanism by turning the hand wheel a slight amount in the opening position. In other words, the throttle hand wheel can be turned in the closing direction a slight amount beyond the point corresponding to throttle closed. This moves the operating relay beyond the position corresponding to the limit of stroke of the operating piston, and the oil supplied to the tripping system passes through the relay opening without building up much pressure.
- (7) The exhaust pressure regulator on the main turbine governor is to be set for a pressure 10 to 15 lb. higher than the normal 200 lb. exhaust header pressure. After once setting, it should not be necessary to change its adjustment. For the initial start, the regulator will be checked to see that it remains at the limit of its stroke calling for more steam.
- (8) Open the valves in the gland steam leakoff lines from the main turbine.
- (9) Adjust the load or steam flow limit valve on the main turbine governor to close this governor about half-way.
- (10) Open the main throttle valve a small amount sufficient to admit steam to raise the turbine rotor speed above that previously held by the turning gear. This small steam flow should pass from the main turbine exhaust directly through the feed heating turbine and out to atmosphere through the 8 in. line, absorbing only a small quantity of this steam in the feed heater. The main turbine exhaust pressure will be far below that existing in the header on the far side of the check valve.
- (11) The turning gear should automatically disengage when the rotor speed is increased and its motor may be shut down after it has been found that the engaging lever is properly latched out of gear. The valve in the oil supply line to the turning gear should then be closed to avoid unnecessary heating and churning of the oil which would otherwise fall onto the coupling.
- (12) Gradually open the throttle valve and in the meantime close down on the main governor by raising the pressure held by the governor regulating valve, maintaining a slow rolling speed of about 200 rpm. As the governor valves are closed and the throttle in the meantime opened, it will finally be found that further opening of the throttle valve is in-effective and control is entirely on the governor valve. When this condition has been reached, the main throttle valve should then be opened wide.
- (13) After rolling at 200 rpm for about twenty minutes and checking the shaft with the indicators provided for the purpose and finding the rotors to be straight, the main turbine exhaust pressure should be gradually raised. This is done by gradually increasing the

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pressure on the feed heat turbine governor operating relay by opening the needle valve in the governor housing. The main turbine exhaust pressure should be raised to the normal value of 200 lb. g. over a period of not less than twenty minutes, meantime keeping the proper rolling speed by manipulation of the spring loaded position valve on the main governor. Obviously, full exhaust pressure cannot be attained until the throttle pressure has increased to something like 300 lb. g. At the end of this operation, the main governor valve will be open to a position determined by the throttle pressure existing at the time. If the throttle pressure is only about 300 lb. the governor valves will presumably be practically wide open. If in the process of bringing up the exhaust pressure in this way, the main valves are open wide before 200 lb. exhaust is attained, it will be necessary to further increase the exhaust only as the throttle pressure increases, leaving the main inlet valves wide open.

- (14) When 200 lb. g. exhaust pressure is reached, the exhaust header check valve should open to pass steam into the low pressure system, and by this time the feed heating turbine governor will be closed or practically closed.
  - (15) Close the feed heating turbine governor, if it is not already in that position, by further increasing pressure supplied by the needle valve. Sufficient ventilating steam will be supplied to this turbine, since the primary inlet valve is adjusted so that it will not close entirely when the governor reaches the end of its stroke.
  - (16) The 8 in. atmospheric relief from the feed heating turbine exhaust may now be at least partly closed; it should not be entirely closed in case this raises the exhaust pressure too high for the liquid seal on the deaerating heater. If it cannot be closed entirely at this time, due to insufficient feed water passing through the deaerating heater to absorb the steam, it may be closed further and finally entirely as the speed of the turbine is increased and the steam flow corresponding increased.
  - (17) As the throttle pressure increases gradually, the speed will also increase. By the combination of increasing throttle pressure and by adjustment of the main governor regulating valve, the speed may be brought to normal under a variety of conditions. For instance, as the throttle pressure increases, the governor regulating valve may be adjusted to gradually close the inlet valves until only the two primary valves are open, in which case full speed should be reached when the throttle pressure has increased to approximately 600 lb. g. and this will require a steam flow of approximately 150,000 lb/h. The governor should assume control at 3600 rpm and if it does not do so, the speed changer should be adjusted until the governor cuts in, then the governor regulating valve should be backed off in order to give the speed responsive element of the governor full range of control.
- See  
Also  
Par.  
17 a
- (17a) As an alternate to the procedure outlined in paragraph (17), it is possible to bring the turbine to speed at considerably lower throttle pressure, but at the same time requiring greater steam flow. If, in accelerating the rotor above the slow rolling speed, the governor valves are opened up to the point of opening the bypass, (the governor may already be in this position as noted in paragraph 13) the speed will increase with increase in throttle pressure and full speed should be reached with about 350 to 375 lb. at the throttle, requiring approximately 250,000 lb/h steam flow. If this is more convenient than the procedure of paragraph 17, it may be followed, there being no preference

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as far as the turbine is concerned. If done in accordance with paragraph 17a, normal speed will be reached with practically full open governor valves instead of only partial open valves.

- (18) At about 2800 rpm, turn on the sealing water to the spindle glands.
- (19) Synchronize.
- (20) To cut in the feed heating turbine governor after synchronizing, back off the feed heating turbine governor speed changer and at the same time gradually close the regulating needle valve, adjusting the speed changer, however, to keep the governor closed until the needle valve has been entirely closed; then gradually advance the speed changer to its full load limit position. The 5 lb. g. exhaust pressure regulator, after proper adjustment, will assume control and will prevent actual opening of the governor beyond the position required to give 5 lb. g. exhaust pressure with whatever waterflow there may be through the deaerating heater.
- (21) The load may be allowed to build up as the throttle pressure increases, leaving the main governor in fixed position, or the speed changer on the main governor may be advanced to open the valves further and pass more steam at fixed throttle pressure. If the turbine is brought to speed and synchronized with practically full open main governor valves and very low throttle pressure, the speed changer need not be further adjusted, as the load will come up to full load as the throttle pressure increases. At this time the load control is on the speed changer, the special governor regulating valves are out of action, and the feed heating turbine is in normal control.
- (22) Open the ventilating steam line connecting the inlet side of the throttle valve to the primary nozzle bowl in the main cylinder.
- (23) See that the oil driven hydrogen seal pump is operating properly, in which case the motor driven seal pump should have automatically shut down when the speed of the turbine reached a point where sufficient oil was supplied to the oil turbine.

### NORMAL SHUTDOWN

Other than for an emergency shutdown, it is assumed that the boiler and the turbine will be brought down together, in which case the following program may be followed to advantage:

- (1) Reduce the boiler rating gradually, allowing the throttle pressure to decrease. If this is done with steam inlet valves in their full load position, the turbine output will drop to zero at about 375 lb. g. throttle pressure and about 250,000 lb/h steam flow.
- (2) When the generator load has dropped to zero, disconnect the generator from the line.
- (3) Close the ventilating steam line from the throttle inlet to the turbine cylinder.
- (4) Continue to lower the throttle pressure, but from this point on the decrease should be made as rapidly as practicable, the turbine speed meantime decreasing.

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- (5) Back off on both governor speed changers to keep both governors active. In the case of the feed heating turbine this means that by manipulation of the speed changer the 5 lb. g. exhaust pressure regulator can be kept in control down to about two-thirds speed. In the case of the main turbine we recommend that the speed changer be backed off sufficiently to keep the bypass steam chest valve from opening in order to avoid changing the condition of heating in the turbine cylinder. By handling the speed changers in this way, both governors remain active down to about two-thirds speed.
- (6) If the feed heating turbine exhaust is not watched carefully, the liquid seal on the deaerating heater may blow, due to insufficient water passing through this heater to absorb the exhaust steam, and the governor getting out of control of the pressure regulator at low speed. This can be avoided by opening the 8 in. atmospheric line from the feed heat turbine exhaust when the speed is dropped to about two-thirds normal.
- (7) Shut off the gland water supply at about 2800 rpm.
- (8) The turbine can be brought to shutdown by continued lowering of the throttle pressure, after which the throttle valve must be closed promptly.
- (9) As the speed decreases, see that the auxiliary oil pump cuts in properly as the lubricating oil pressure drops.
- (10) See that the motor driven hydrogen shaft seal pump cuts in automatically as the oil driven pump slows down.
- (11) As soon as the turbine has stopped and the throttle valve has been tripped, start the motor driven auxiliary oil pump, shut down the steam driven pump, and engage and start up the turning gear.
- (12) Close the 200 lb. header gate valve.
- (13) Open the cylinder drains.

### STARTING WITH FULL THROTTLE PRESSURE

The comments regarding the general features of the turbine given in the beginning apply equally well here, and need not be repeated. Under the particular conditions of this installation, it is expected that starting with full throttle pressure will not be required until superposition is extended in the plant, when it may become necessary to start with steam not only at full pressure but also at any temperature up to 900° F.

For such a start it is assumed that conditions are as stated previously in paragraphs (a), (b), (c), and (d) for a low pressure start, and that the throttle steam pressure is approximately 1200 lb. g.

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- (1) Same as bringing boiler and turbine up together, paragraph 1.
  - (2) Same as bringing boiler and turbine up together, paragraph 2.
  - (3) Same as bringing boiler and turbine up together, paragraph 3.
  - (4) Same as bringing boiler and turbine up together, paragraph 4.

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- (5) Same as bringing boiler and turbine up together, paragraph 5.
- (6) Same as bringing boiler and turbine up together, paragraph 6.
- (7) Same as bringing boiler and turbine up together, paragraph 7.
- (8) Same as bringing boiler and turbine up together, paragraph 8.
- (9) Same as bringing boiler and turbine up together, paragraph 9.
- (10) Same as bringing boiler and turbine up together, paragraph 10.
- (11) Same as bringing boiler and turbine up together, paragraph 11.
- (12) After rolling at 200 rpm for about thirty minutes and checking the shaft with the indicators provided for the purpose and finding the rotors to be straight, the main turbine exhaust pressure should be gradually raised. This is done by gradually increasing the pressure on the feed heat turbine governor operating relay by opening the needle valve in the governor housing. The main turbine exhaust pressure should be raised to the normal value of 200 lb. g. over a period of about twenty minutes, meantime keeping the proper slow-rolling speed by further opening of the throttle valve.
- (13) Same as bringing boiler and turbine together, paragraph 14.
- (14) Same as bringing boiler and turbine up together, paragraph 15.
- (15) Same as bringing boiler and turbine up together, paragraph 16.
- (16) After operating a few minutes at 200 rpm with 200 lb. g. exhaust pressure, gradually open the throttle valve to accelerate at the rate of about 100 rpm per minute to normal speed, where the governor should assume control. If it does not, the speed changer should be adjusted until it does.
- (17) Back off the spring load on the main governor position regulating valve so as to take this valve entirely out of the range of action and give the speed governor control over full governor travel.
- (18) Same as bringing boiler and turbine up together, paragraph 18.
- (19) Same as bringing boiler and turbine up together, paragraph 19.
- (20) Same as bringing boiler and turbine up together, paragraph 20.
- (21) Increase load by adjustment of the speed changer. This should be done in steps of about 5000 Kw load increase at five minute intervals. The feed heating turbine governor is now in normal operating adjustment, under the control of the 5 lb. g. pressure regulator over its full range of travel.
- (22) Same as bringing boiler and turbine up together, paragraph 22.
- (23) Same as bringing boiler and turbine up together, paragraph 23.