GE Energy

Steam Seal System Requirements

(For Combined Cycle Steam Turbines)
also applicable to industrial SC (Straight Condensing) Series Turbines

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes the matter should be referred to the GE Company.

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I. STEAM SEAL SYSTEM DESCRIPTION

A shaft sealing system is required to seal the turbine end packings so that vacuum may be established within the turbine prior to startup. During startup and normal operation, sealing must be maintained so that air does not leak into the sub-atmospheric section of the turbine, and excess steam in the high-pressure section of the machine does not blow out into the turbine room or into bearing housings to contaminate lubricating oil.

At startup, sealing is achieved by introducing steam between intermediate packing rings and venting between outer packing rings to a gland exhauster. The gland exhauster system prevents steam from escaping into the turbine room by establishing a sub-atmospheric pressure between the two outer rings of packing. Air is thus drawn in through the last ring of packing, and steam enters this cell from the opposite direction. This steam and air mixture is piped to the gland exhauster where the steam is condensed by cold feedwater flow through the primary side of a heat exchanger, and the air is evacuated by means of a centrifugal blower. The gland exhauster system is described in detail in GEK 107384.

As steam turbine load increases, the steam flow out of the high pressure section end packings and the reheat section inlet (reheat units only) end packings reaches a point where it is sufficient to provide 100% of the sealing steam for the LP section end packings. The turbine is said to be “Self-Sealed” above this load level (i.e. when the steam seal feed valve goes 100% closed and the steam seal dump valve opens). The excess steam from the high-pressure packings, over that required for sealing the low-pressure end, is diverted to the condenser. Control of these steam flows is maintained by a steam seal regulator which maintains the steam seal manifold pressure at a constant 18.7 psia (129 kPa) by admitting or dumping steam through the steam seal feed or steam seal dump valves.

A SERIES TURBINE

Figure 1 shows the direction of sealing steam flows during turbine startup conditions for typical A series combined cycle turbines. Figure 2 shows the direction of sealing steam flows above the turbine self-sealing point.

In Figure 2, the flow of steam from the HP section end packings and the RH section inlet end packings have been reversed, and steam flow in excess of that required to seal the LP end packing is dumped to the condenser. At the same time, steam flow from the outside source has been shut off by the steam seal feed valve. Figure 11 and Figure 12 show steam flow direction within the high pressure exhaust end packing of the turbine.

D SERIES TURBINE

Figure 3 shows the direction of sealing steam flows during turbine startup conditions for typical D series combined cycle turbines. Figure 4 shows the direction of sealing steam flows above the turbine self-sealing point.

In Figure 4, the flow of steam from the HP section end packings and the RH section inlet end packings have been reversed, and steam flow in excess of that required to seal the LP end packing is dumped to the condenser. At the same time, steam flow from the outside source has been shut off by the steam seal feed valve.Figure 11 and Figure 12 show steam flow direction within the high pressure exhaust end packing of the turbine.

STRAIGHT CONDENSING (NON REHEAT) SERIES TURBINES

Figure 5 shows the direction of sealing steam flows during turbine startup conditions for a typical non-reheat (straight condensing) type turbines. Figure 6 shows the direction of sealing steam flows above the turbine self-sealing point.

II. IMPACT OF STEAM SEAL SUPPLY CONDITIONS ON THE STEAM TURBINE

Sealing steam from an external source must be supplied to the steam seal header when the steam turbine is on turning gear with steam seals on, during startup with the turbine below the self-sealing point, and during shutdown. Supplying sealing steam at optimal temperature, pressure, and quality (moisture content) levels is necessary to avoid conditions which can adversely effect startup robustness. Because steam seal supply pressure is maintained at a constant 4 psig (28 kPa) by automatically admitting or dumping steam through the steam seal feed or steam seal dump valves and steam quality is a function of temperature and system drain design, the primary characteristic which remains to be controlled is steam seal supply temperature.

The optimal steam seal supply temperature is that which:

- Prevents Water/Wet Steam Induction Through The Steam Seal System
- Prevents Long/Short Rotor Axial Differential Expansion Problems
- Maintains Radial Clearance Control Between Rotating And Stationary Parts
- Minimizes Thermal Fatigue Of Turbine Parts
- Prevents Turbine Seals and Parts From Being Exposed To Temperatures Above Allowable Limits

A. Water/Wet Steam Induction Through The Steam Seal System

Water/Wet steam induction through the steam seal system can be avoided by assuring there is superheated steam in the steam seal header at all times and by designing steam seal system piping and drains in accordance with GE Drawing 244A5881 requirements. Preventing the induction of water/wet steam into the turbine through the steam seal system both prior to and following turbine startup is critical to avoid short rotor axial rubs and radial rubs caused by the asymmetric distortion of stationary components.

B. Axial Differential Thermal Expansion

Differential axial thermal expansion relative to the turbine thrust bearing results whenever temperature mismatch exists between the sealing steam and inlet metal. Steam supplied to the high pressure and reheat inlet packings from the steam seal header heats and cools the rotor more quickly than the shell because the shell thermal mass is generally larger than the rotor thermal mass and heat transfer is greater at the rotor surface. Thus, if the sealing steam is hotter than the turbine inlet metal (typical of a cold start), the rotor axial thermal growth rate will be larger than the shell axial growth rate resulting in “long-rotor” (rotor longer than shell) differential expansion. When sealing steam is colder than the turbine inlet metal (typical of a hot start), the rotor axial thermal shrinkage rate will be larger than the shell axial shrinkage rate resulting in “short-rotor” (shell longer than rotor) differential expansion. Axial clearances within the turbine are designed to accommodate long rotor and short rotor growths for typical cold, warm and hot start conditions without axial rubbing. Axial clearances are not designed to accommodate excessive temperature mismatches between the sealing steam temperature, and the inlet metal temperature.

It should be noted that the high pressure and intermediate/low pressure section differential expansion detection systems provide indication of total differential expansion at the axial location where the detection devices are mounted. Steam seal supply temperature variation outside GE recommended limits may result in large localized differential expansion in the area where sealing steam is applied without causing total HP or total IP/LP differential expansion to approach alarm or trip limits.

C. Radial Clearance Control

Whenever temperature mismatch exists between the sealing steam and inlet metal, radial packing clearances in the turbine end packing regions can be effected. The two mechanisms which can impact radial clearances are packing casing distortion and radial differential expansion between the rotor and packing teeth. Positive mismatch (steam temperature higher than metal) between seal steam supply temperature and turbine metal is generally beneficial to maintaining adequate radial clearance control at the end packing regions. Substantial negative mismatch (steam temperature lower than metal) between seal steam supply temperature and turbine metal can result in reduced radial clearances and can contribute to radial rubbing during transient operation.

D. Rotor Thermal Fatigue Life

Excessive mismatches between sealing steam and turbine rotor temperatures can cause high thermal stresses at the rotor surface in the packing area. Each thermal stress cycle consumes a portion of the metal cyclic life, and repeated subjection of the rotor to large mismatch temperatures can result in thermal fatigue cracking at the rotor surface. Operation with steam seal temperatures within the ranges will maximize the fatigue life of the turbine rotor in the end packing region.

E. Material Limitations

The LP section rotor and casing material are designed to withstand exposure to steam conditions below 750°F. As such, when the steam turbine is on turning gear with steam seals on, during startup with the turbine below the self-sealing point, during operation above the self-sealing point and during shutdown, sealing steam below 750°F must be supplied to the low pressure packings to avoid damaging LP turbine components. Seal piping in the exhaust hood is designed to cool the sealing steam being supplied to the LP end packing region. Above the self-sealing point, turbine flow is high enough to cool the steam which is coming from the HP end packings and the IP inlet packing (reheat units only) below 750°F. At low loads, the amount of cooling provided in the exhaust hood is reduced due to reduced main steam flow. To account for this reduced cooling, the steam supplied to the steam seal header must be limited to 750°F at low loads

III. OPTIMAL SEALING STEAM TEMPERATURE

Optimal sealing steam temperature when the steam turbine is on turning gear with steam seals on, during startup with the turbine below the self-sealing point, and during shutdown is that temperature which prevents water/wet steam induction, keeps long/short rotor differential expansion below allowable limits, avoids radial end packing rubs, minimizes rotor fatigue life expenditure, and prevents LP components from damage due to over temperature.

A SERIES TURBINES

Figure 7 provides the design basis steam auxiliary supply temperature requirements as a function of the turbine thermal state (average of the HP and RH bowl metal temperatures) at any given time.

A14 AND A15 CODE TYPE UNITS ONLY

The steam turbine control system will continuously calculate the optimal seal steam temperature from the turbine viewpoint and provide a reference steam seal supply temperature signal to the plant DCS control system. When actual steam seal supply temperature deviates outside of the acceptable variation band, the steam turbine control system will take actions necessary to protect the turbine components. Protective actions may include: startup prevention (prior to startup) and alarms (following startup). The best corrective action will always be to supply sealing steam at temperatures as close as possible to the turbine control system optimum reference signal.

D SERIES TURBINES: MULTI SHAFT

Figure 8 provides the design basis steam auxiliary supply temperature requirements as a function of the turbine thermal state (average of the HP and RH bowl metal temperatures) at any given time.

D SERIES TURBINES: SINGLE SHAFT

Figure 9 provides the design basis steam seal header temperature requirements as a function of the turbine thermal state (average of the HP and RH bowl metal temperatures) at any given time.

SC SERIES TURBINES

Figure 10 shows the design basis steam auxiliary supply temperature requirements as a function of the turbine thermal state (function of HP bowl temperature) at any given time.

All steam temperatures on Figures 7–10 are after steam has been throttled to header pressure of 4 psig (28 kPa). An optimum temperature and allowable variation bands above/below the optimum are provided. At all times when steam seals are on, steam seal header temperature must be above 300°F to prevent water/wet steam induction into the turbine. For cold starts (Bowl Metal temperature <400°F), steam seal header temperature should be set low in the range to manage long rotor differential expansion, and rotor fatigue life. For warm starts (400< Bowl Metal temperature < 700°F), steam seal header temperature should be set in the middle of the range. For hot starts (Bowl Metal temperature > 700°F), steam seal header temperature should be set high in the range to manage short rotor differential expansion, rotor fatigue life and radial clearance control.

IV. DESIGN INFORMATION FOR THE STATION DESIGNER

For Information on the steam seal header feed and dump valve see the steam turbine P&ID (customer drawing item VD01). For Information on steam seal header connection points see steam seal connection outline (customer drawing item VS01). For steam seal piping design requirements see GE drawing 364A7166.

The station designer should recognize that the throttling of the steam from the source to the header (held at 4 psig) reduces the steam temperature. For example, if a 100 psia auxiliary source were selected then a minimum of 340°F temperature would be required for that source. The station designer shall account for temperature drops associated with pressure drops when designing the auxiliary supply system by consulting a Mollier steam property diagram.

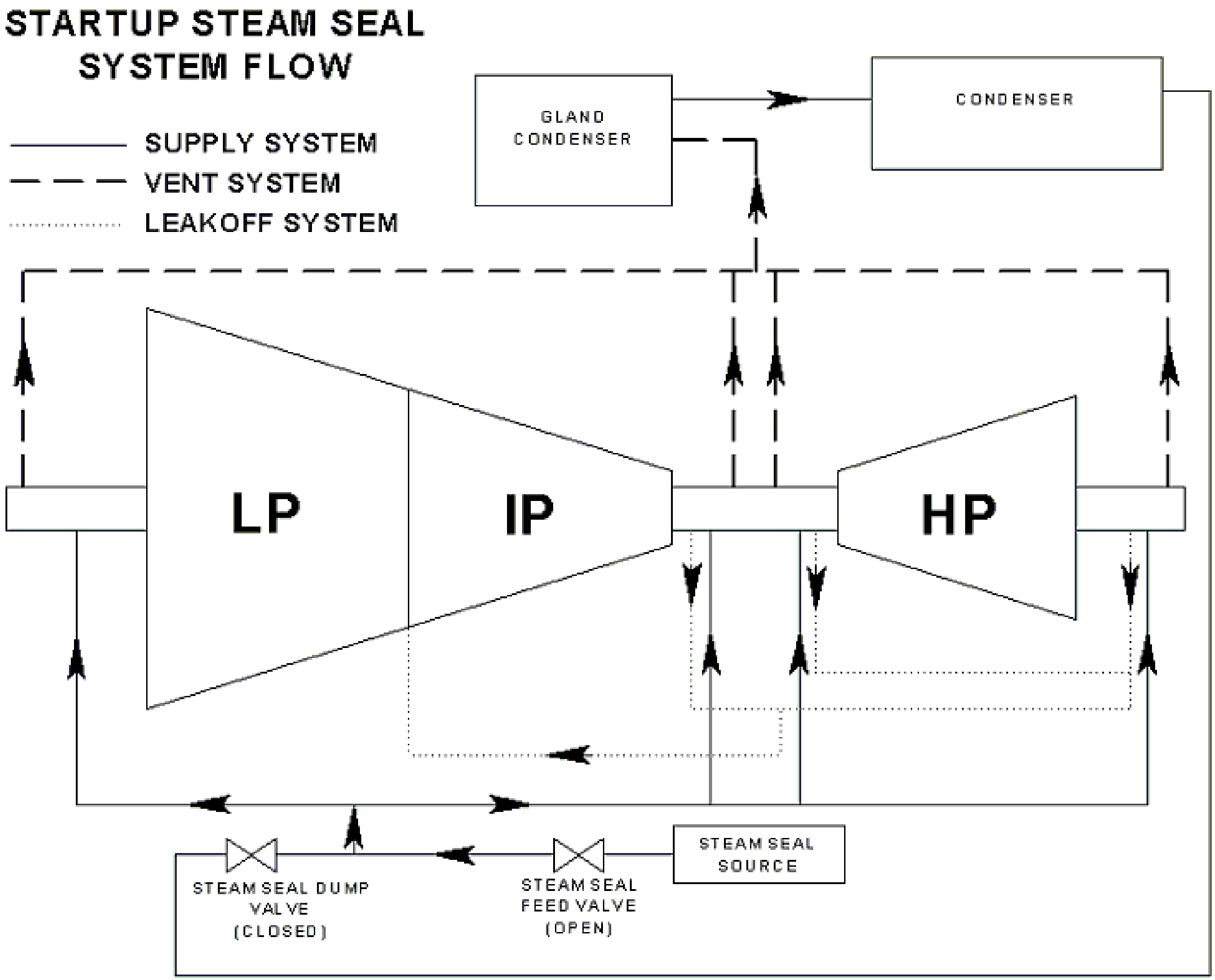

Figure 1. Steam Flow at Startup: A Series

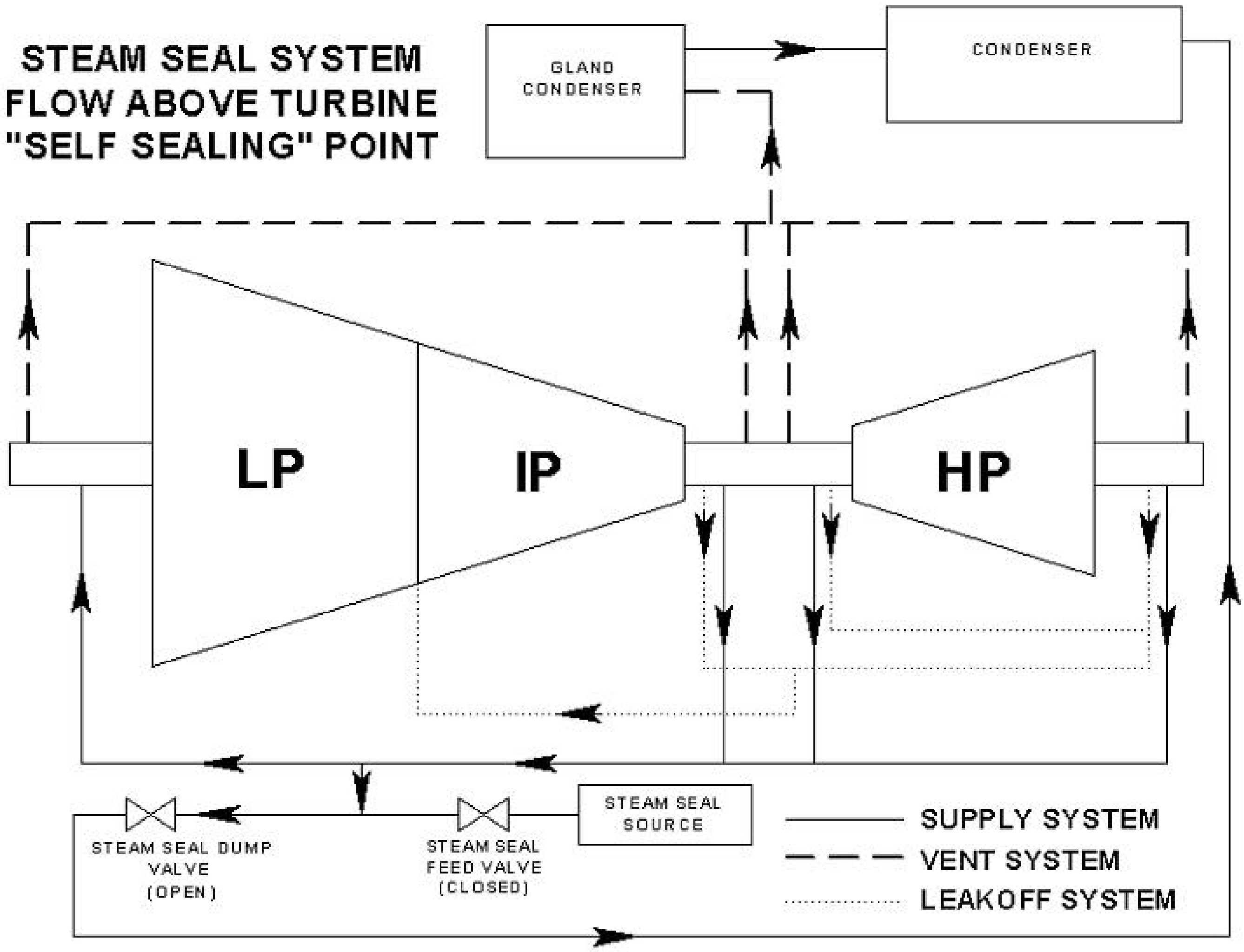

Figure 2. Steam Flow During Operation: A Series

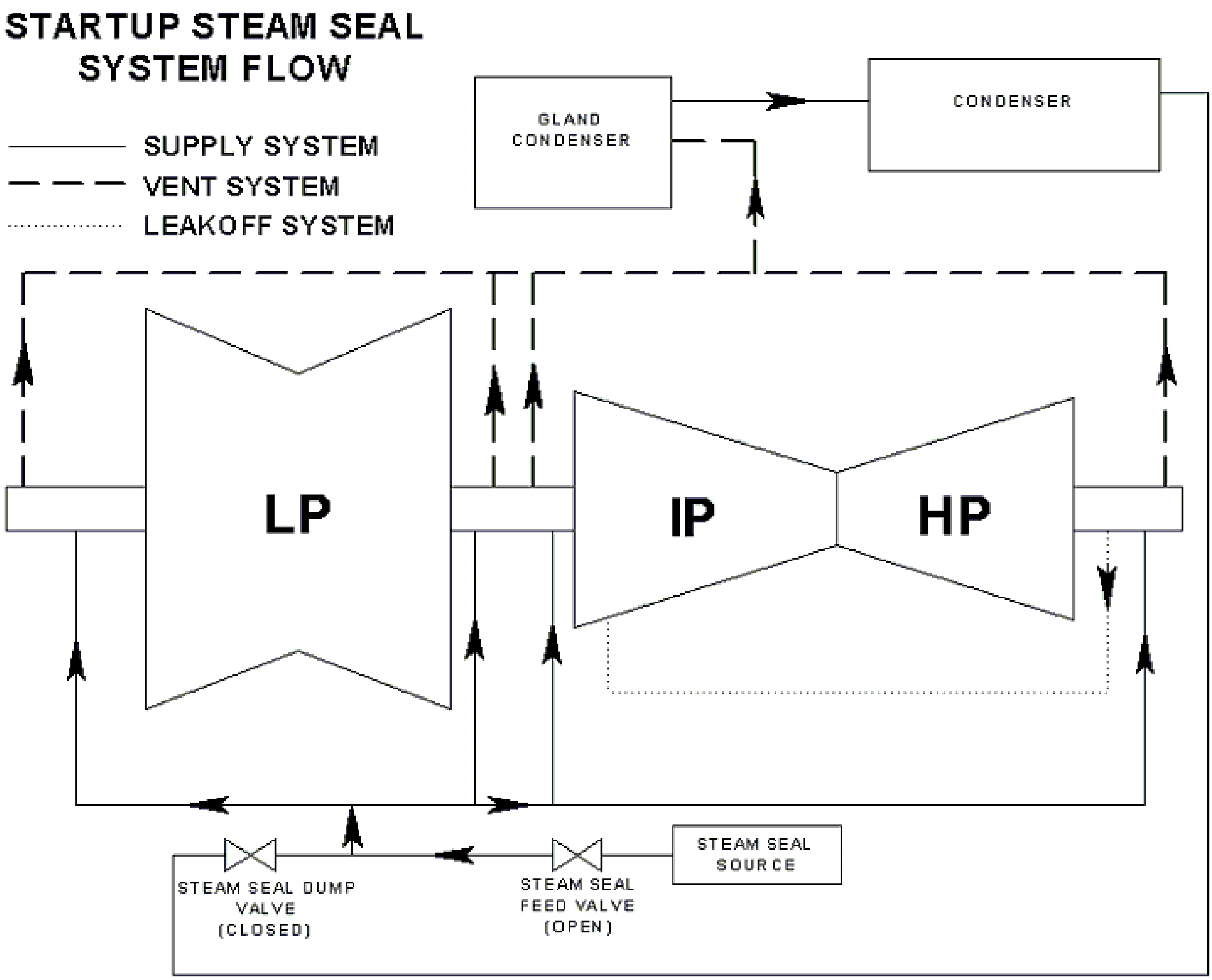

Figure 3. Steam Flow at Startup: D Series

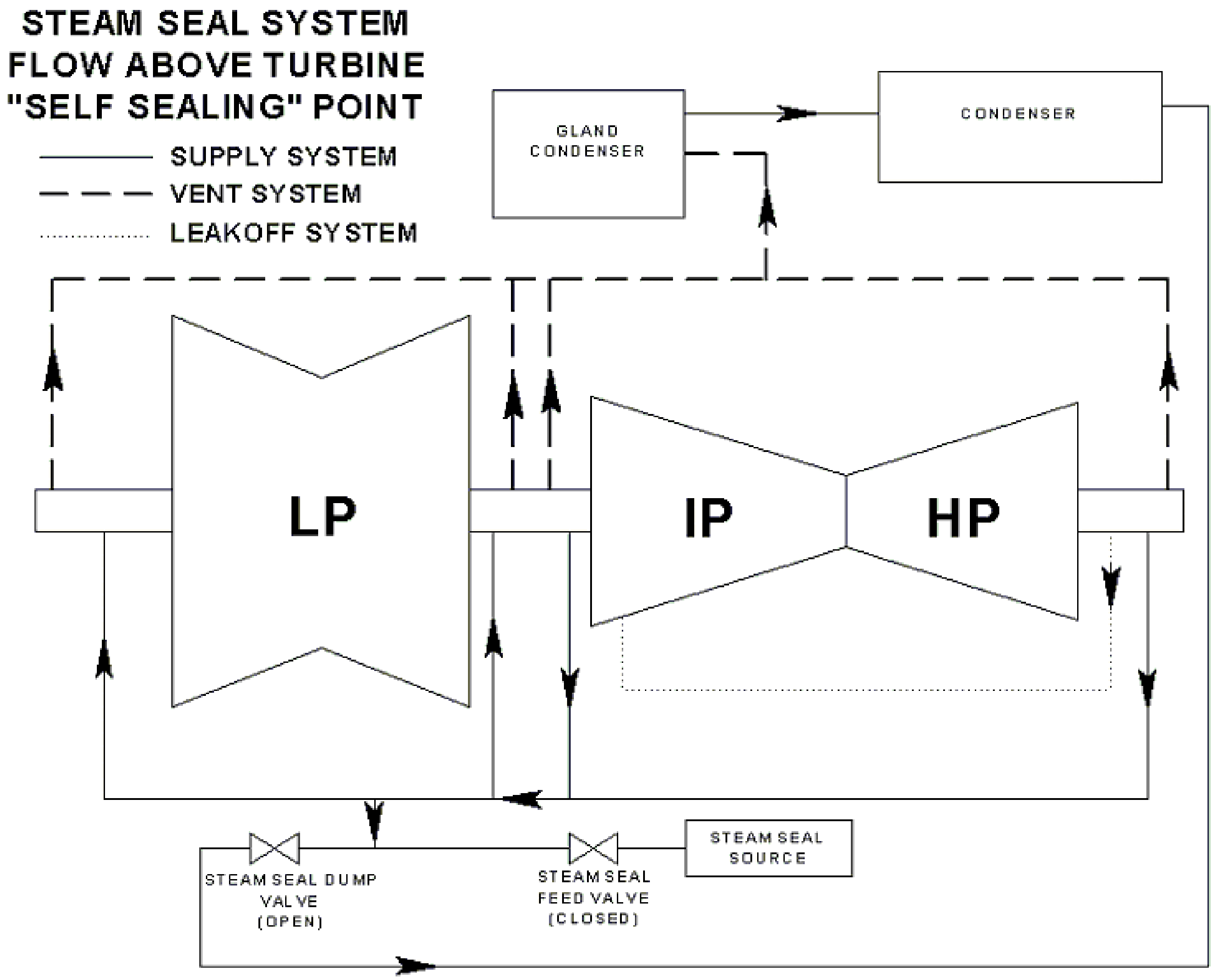

Figure 4. Steam Flow During Operation: D Series

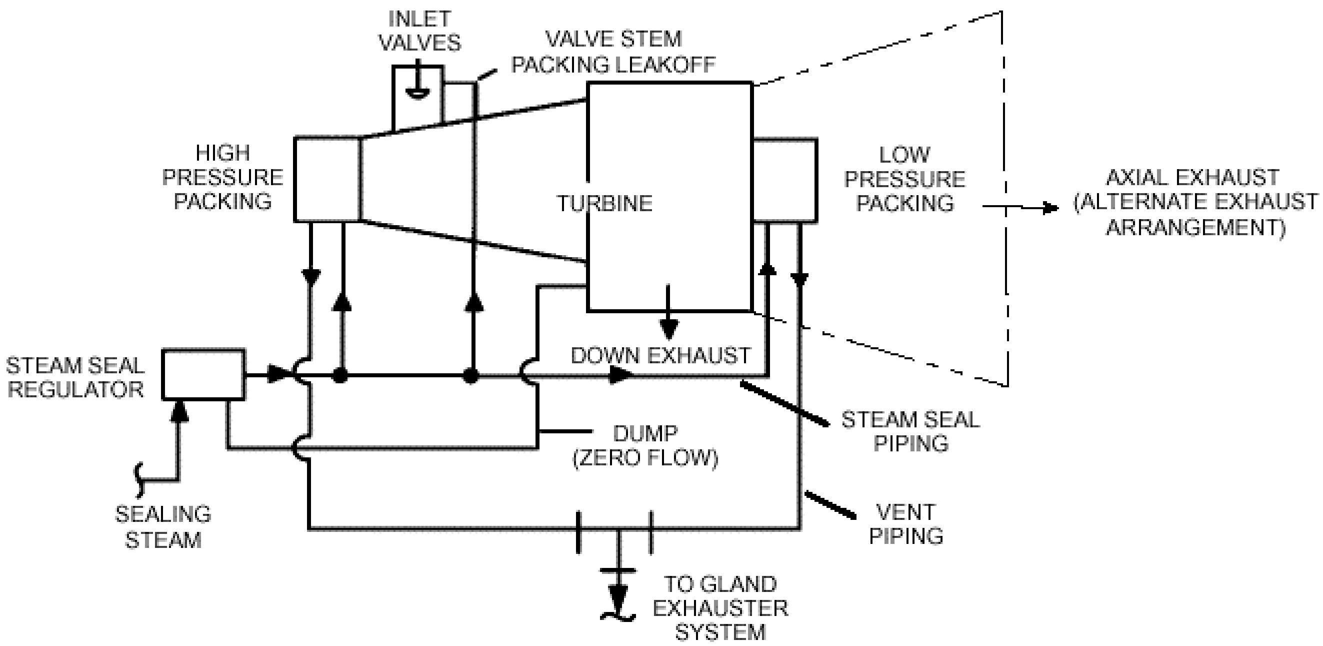

Figure 5. Steam Flow at Startup: SC Series

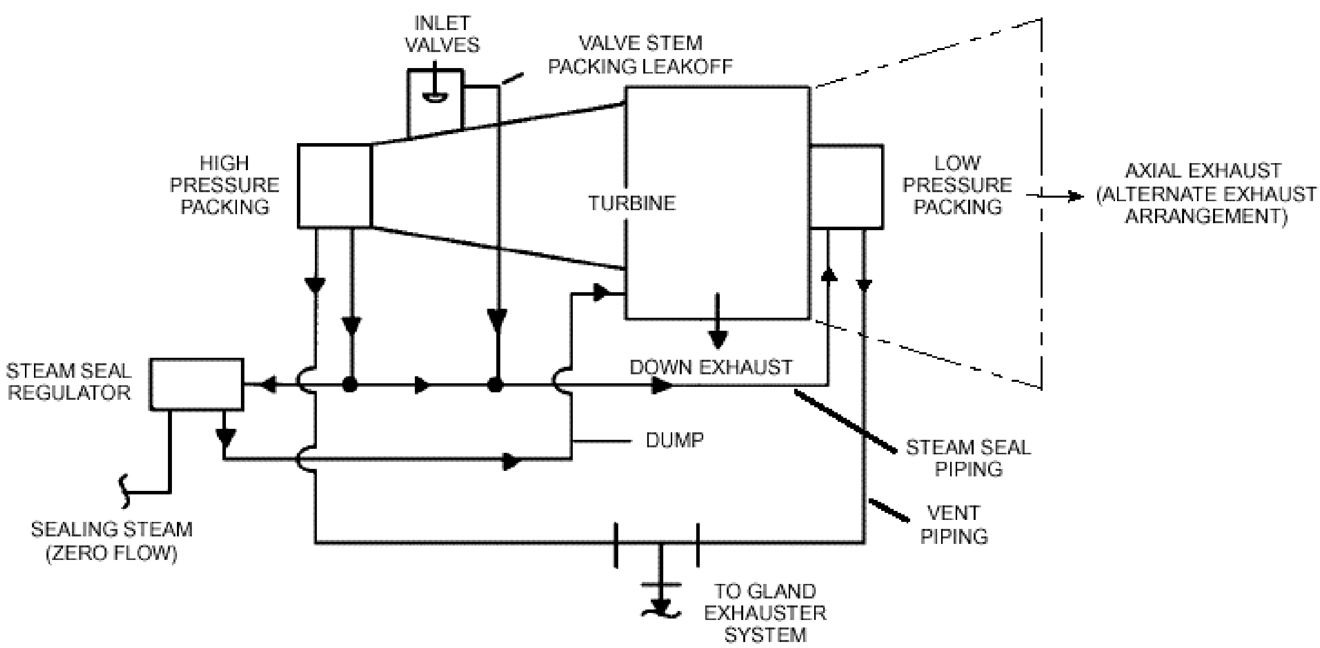

Figure 6. Steam Flow During Operation: SC Series

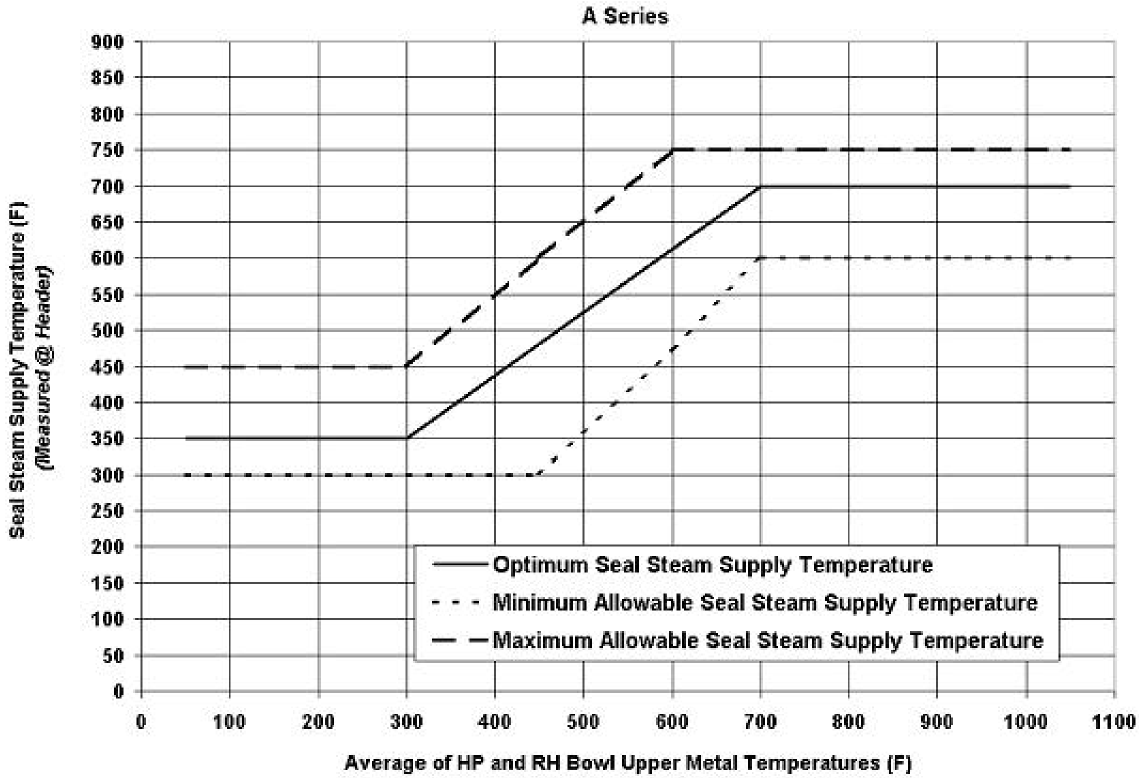

Figure 7. Steam Seal Temperature Requirements: A Series

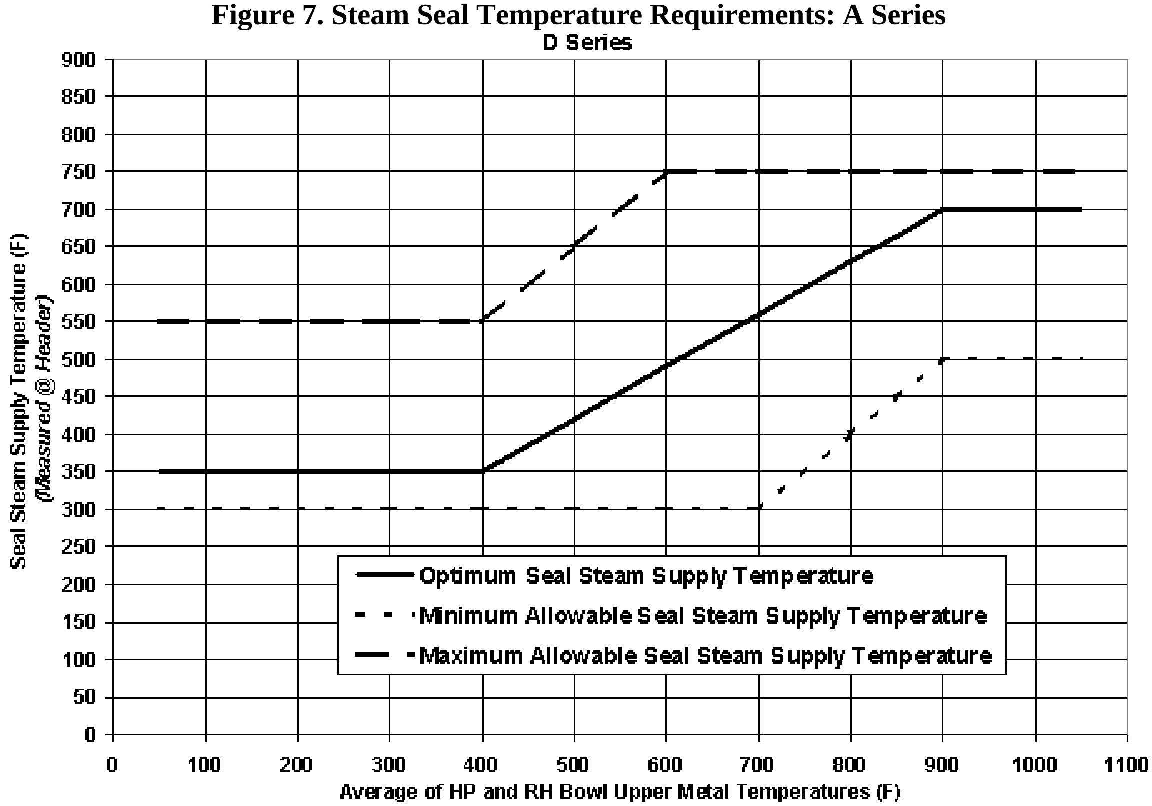

Figure 8: Steam Seal Temperature Requirements: D Series Multi Shaft

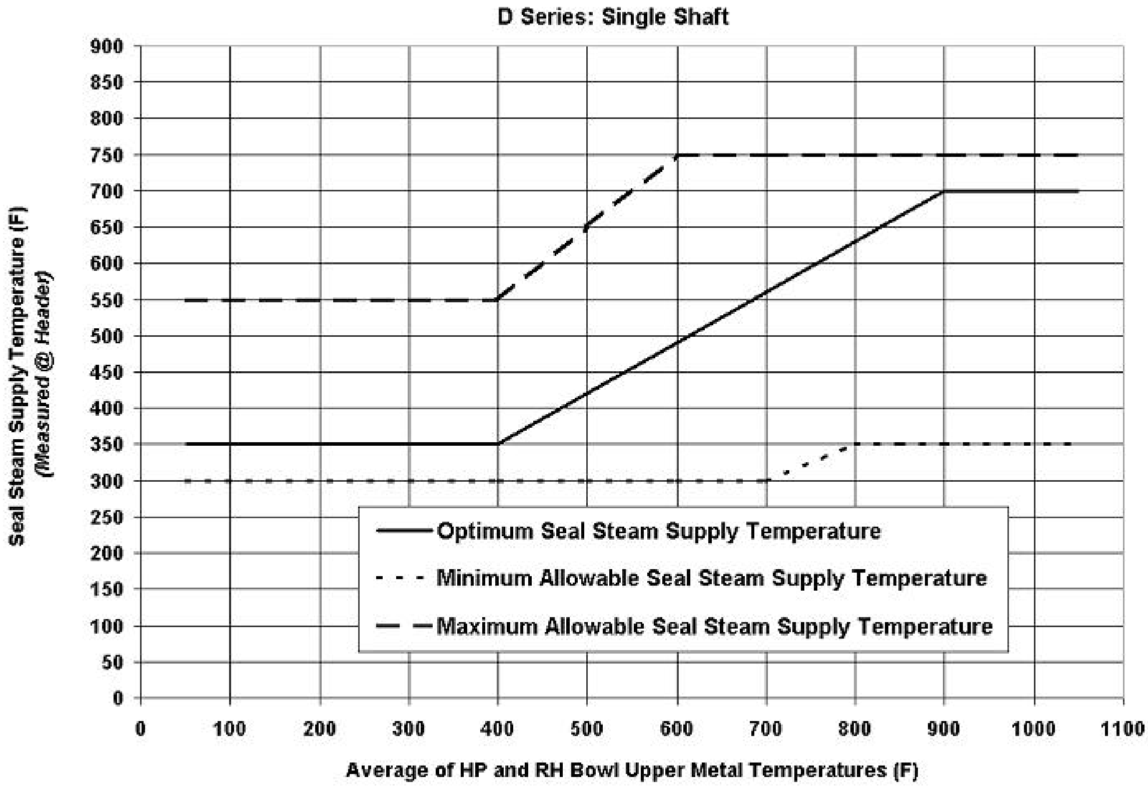

Figure 9: Steam Seal Temperature Requirements: D Series: Single Shaft

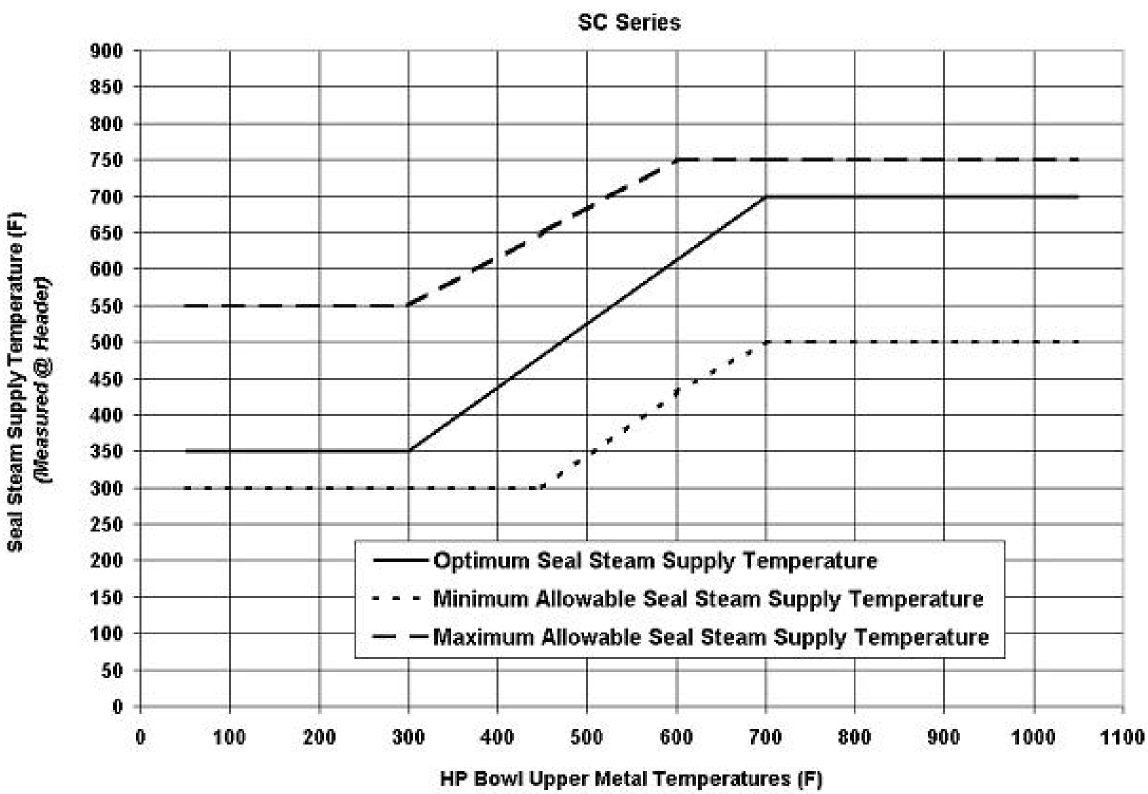

Figure 10. Sealing Steam Temperature Requirements for SC Series

Typical Endpacking Flow Direction During Startup Operation

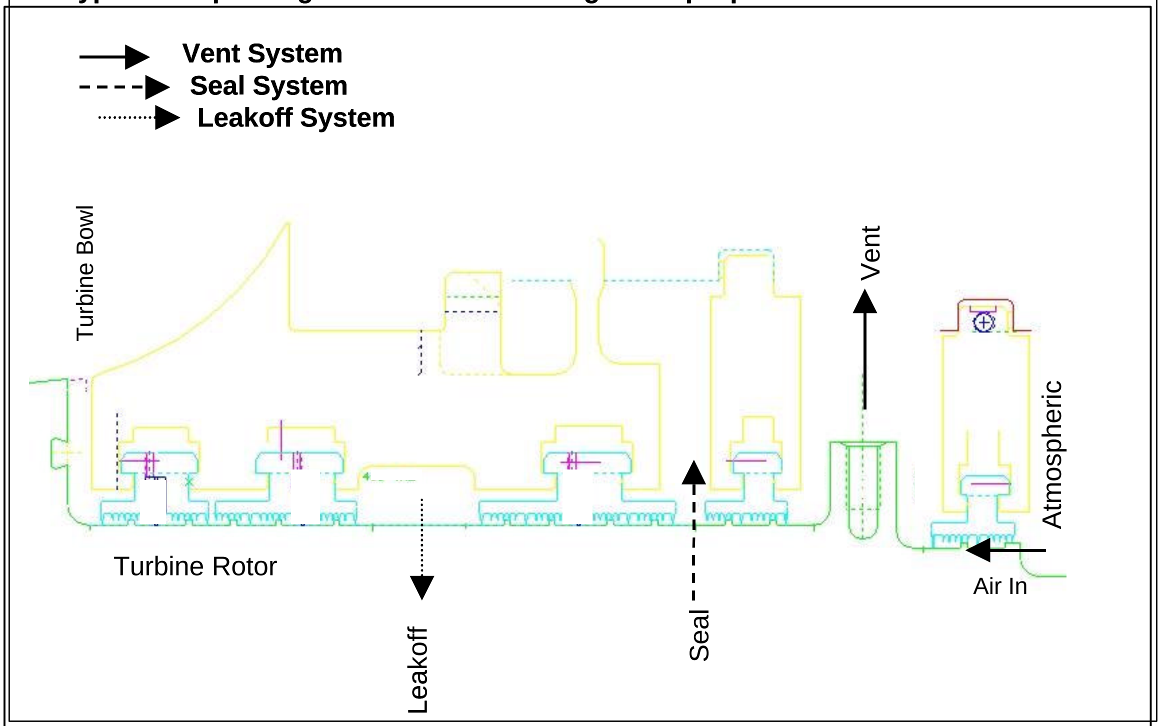

Figure 11. Endpacking Cross Section Steam Flow During Startup

Typical Endpacking Flow Direction During Self Sealing Operation

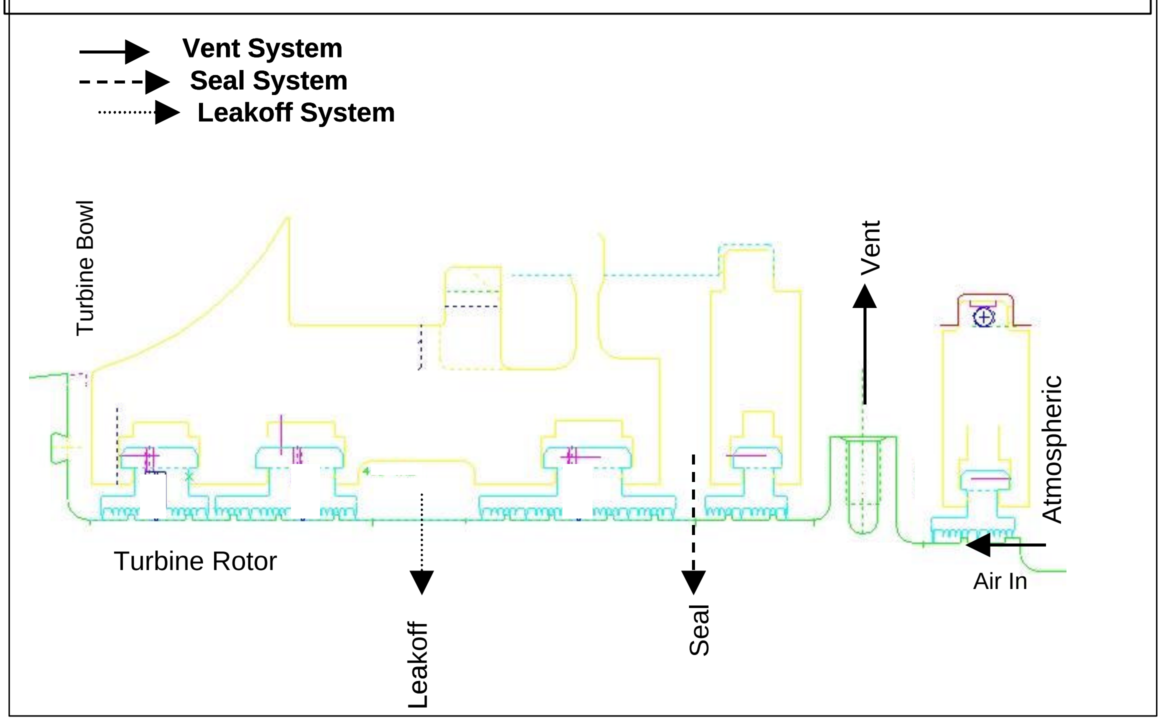

Figure 12. Endpacking Cross Section Steam Flow During Self Sealing Operation

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