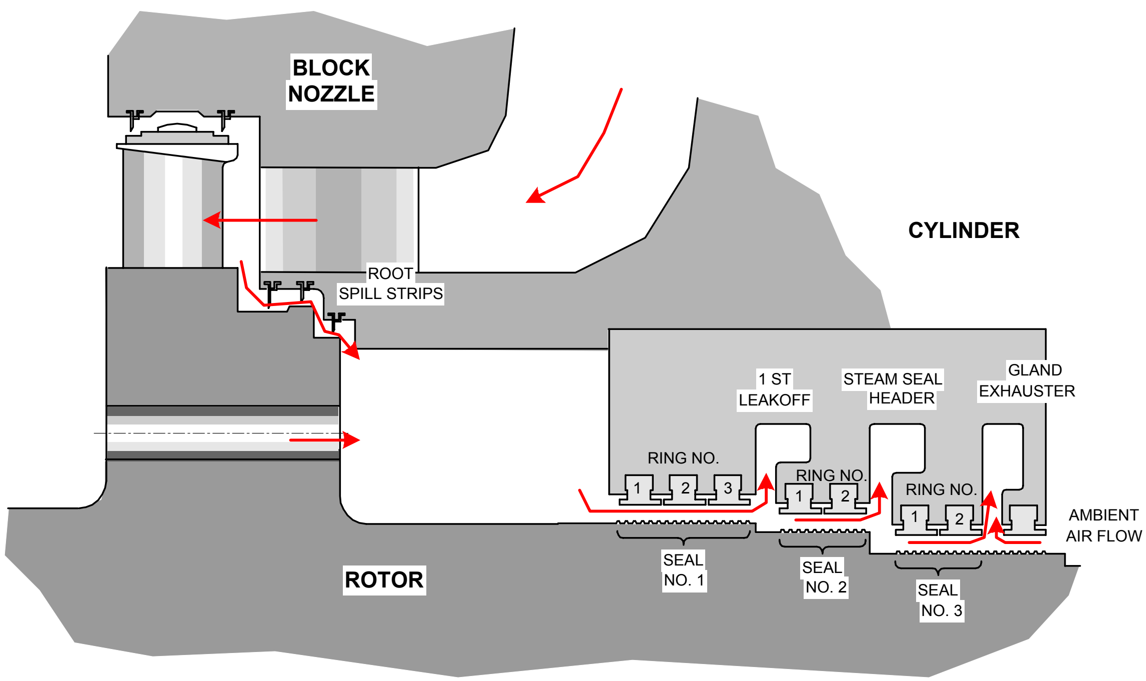
Leakage control Devices

The leakage control devices we will be discussing here are:

1) Turbine shaft end packings
2) Packings, or seals, limiting the flow around and through the stage components.

Figure 1 shows a typical HP turbine shaft seal.

Figure 1



In addition to flowing downstream through the stage blading, steam is leaking radially inward and then out of the HP shell between the shaft and the stationary casing. To limit this flow there are stationary (and sometimes rotating) teeth that provide resistance to this leakage flow by introducing a series of pressure drops. Also there are occasional leakoffs where some of the leakage steam is diverted to an extraction line or to a "steam seal header" maintained at a pressure a little above atmospheric. A last leakoff is connected to a "gland exhauster header" which is maintained at a pressure slightly below atmospheric and prevents steam from leaking into the turbine room.

Figure 2 shows the leakage paths through a typical wheel and diaphragm (impulse) type stage and Figure 3 through a typical drum type rotor (reaction) design stage.

Figure 2

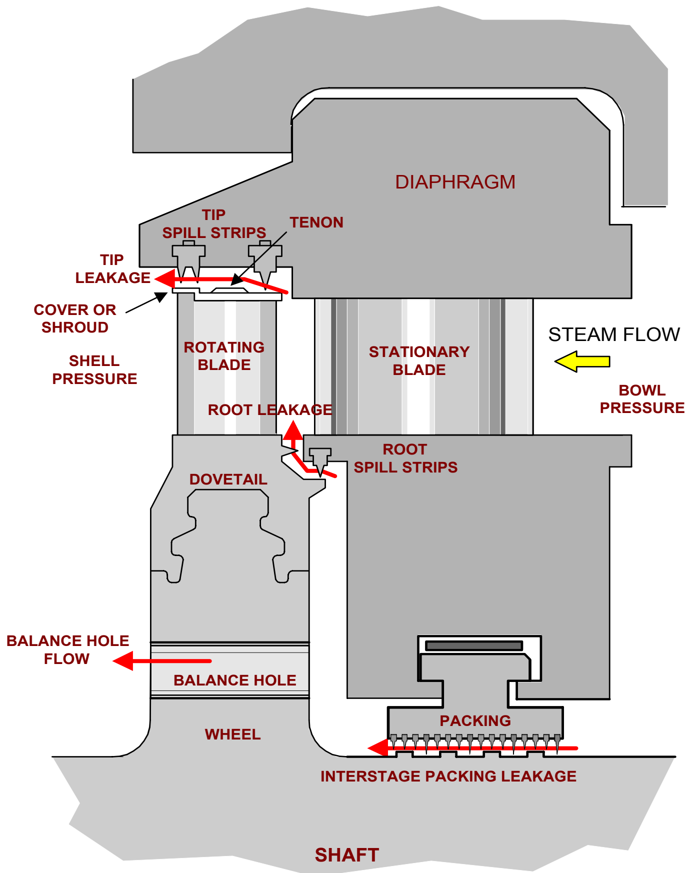
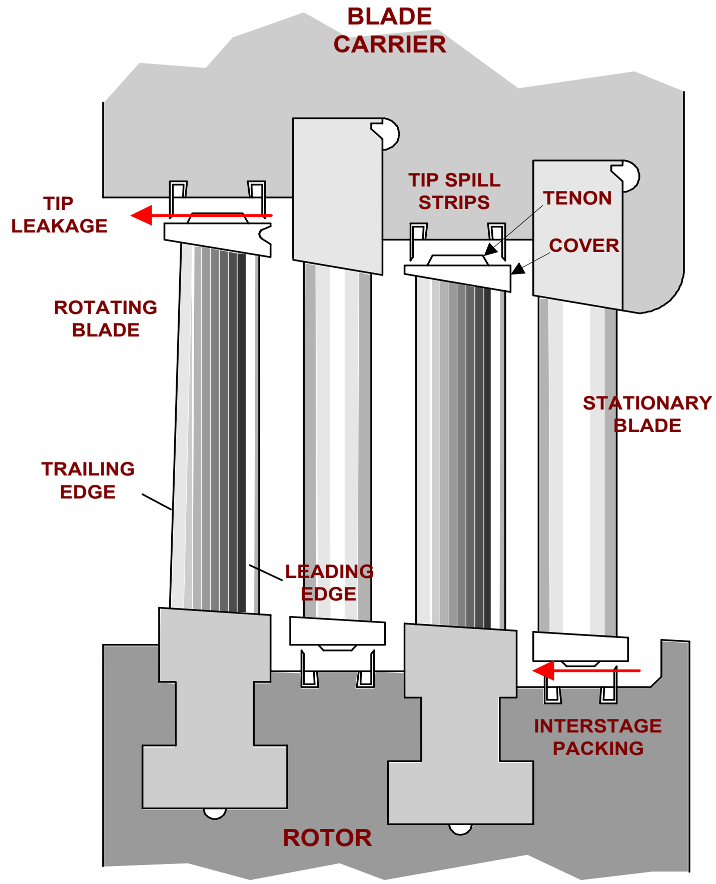


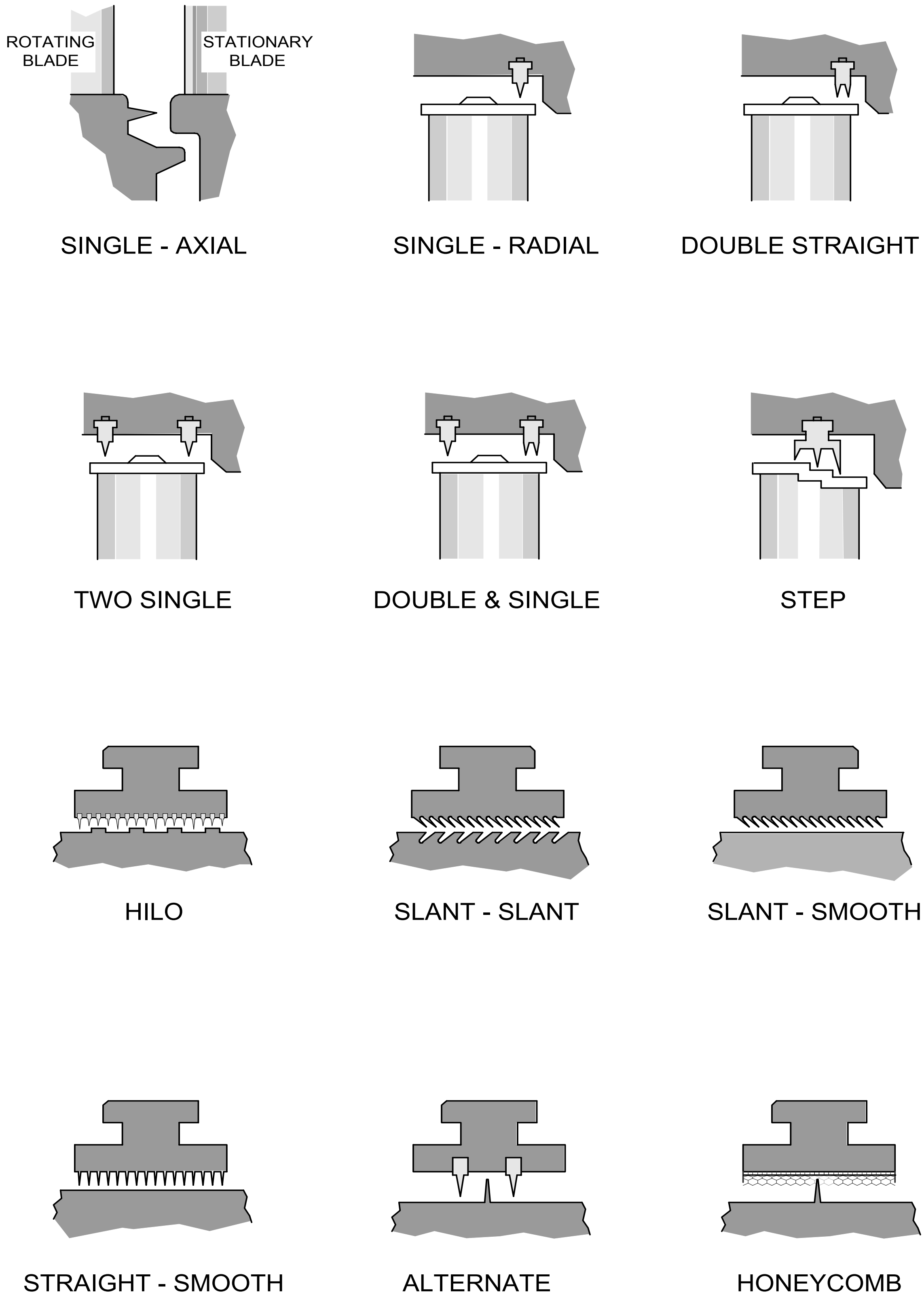
Figure 3



In each case, in addition to flowing downstream as desired, steam is leaking between the stationary blading and the rotor body and between the tip of the rotating blading and the stationary diaphragm or blade carrier. As with the shaft end packings, there are seals provided which provide one or more restrictions to minimize these leakage flows.

Figure 4 shows the twelve common types of seal types that are included in the Encotech, Inc. eSTPE program.

Figure 4


ROTATING BLADE
STATIONARY BLADE
SINGLE - AXIAL
SINGLE - RADIAL
DOUBLE STRAIGHT
TWO SINGLE
DOUBLE & SINGLE
STEP
HILO
SLANT - SLANT
SLANT - SMOOTH
STRAIGHT - SMOOTH
ALTERNATE
HONEYCOMB

Obviously, the smaller the clearance between the tips of the various types of seals in Figure 4, and the adjacent rotating or stationary part, the less is the undesirable leakage.

It should be noted here that the tips of the teeth in these seals are initially quite sharp. This is because a sharp tooth tip produces a greater resistance to flow than a broad one, and what is even worse from a flow minimization standpoint, is to rub a tooth tip, which produces a mushroomed and rounded surface that greatly reduces the flow restricting capability. To minimize the rubbing and resultant rounding of the teeth tips, the turbine designer establishes some minimum, or design, clearance that is used when new seals are installed.

These seal teeth are rather delicate, and so they do get rubbed and mushroomed to some degree, eroded, damaged by foreign objects, or otherwise have the clearance available for leakage flow increased while the unit is in service.

The problem during a steam path audit is to first determine the amount of increased clearance, and the amount of rounding of tooth tips, and then determine the magnitude of the increased leakage flow. The increased clearance is determined by careful measurements and the amount of rounding by observation as a proportion of, none to fully rounded, around the entire circumference.

To calculate the change in leakage flow it is necessary to know the steam pressure and specific volume immediately upstream of the seal and the pressure immediately downstream.

For the turbine stage, identifying the required pressures and temperatures can be difficult because neither this information, nor the steam conditions at the stage inlet and discharge, are given in any normally available documents. Furthermore the steam conditions between the stationary and rotating blades are different at the root from those at the tip, and these conditions are needed to accurately calculate both the leakage past the stationary blading (sometimes called diaphragm packing) and past the tip of the rotating blades, often called tip spill strips.

The Encotech, Inc. eSTPE program resolves this dilemma by making use of the steam properties information available on a full load heat balance, in a “Design” program which distributes the available energy across the various stages in the same manner as a turbine designer does in the design of the turbine. Knowing the blade heights and root diameters, stage reaction, and speed of rotation the “Design” program can then calculate the root and tip pressures between the stationary and rotating blades. It is then possible, using data entered by the steam path auditor, to calculate the increased clearance and degree of roundness; and then the increased leakage flow and the resulting loss of power output and the increase in heat rate.

For the shaft packings it is easier to determine the steam properties forcing steam through the packing and at the various leakoffs. In addition it is necessary to determine the portion of the turbine that has been bypassed and the impact on the boiler duty, which is needed for calculating changes in heat rate.

For turbine stage seals, such as tip spill strips, it is interesting to normalize the individual packing loss by dividing by the increased clearance in mils (0.001 in) and get a parameter whose units are kW loss/mil excess clearance. At first you might expect this to be a constant, or vary in some regular way throughout the turbine. However, there are a number of situations that can affect this parameter:

1) Differences in the amount of rounding
2) Differences in the stage energy
3) Differences in the seal type
4) Decreasing loss recovery in latter stages of a casing
5) Leakage is increasingly a larger portion of the main flow in earlier stages of a casing
6) Radial height of the blading, i.e., the size of the unit
7) Number of parallel flows

The eSTPE Design and Audit analysis program, of course, takes account of all these characteristics. The following Figures 5 and 6 show HP turbine radial spill strip data for seven units, selected from the eSTPE Audit Library, of about 100 audits.

Figure 5

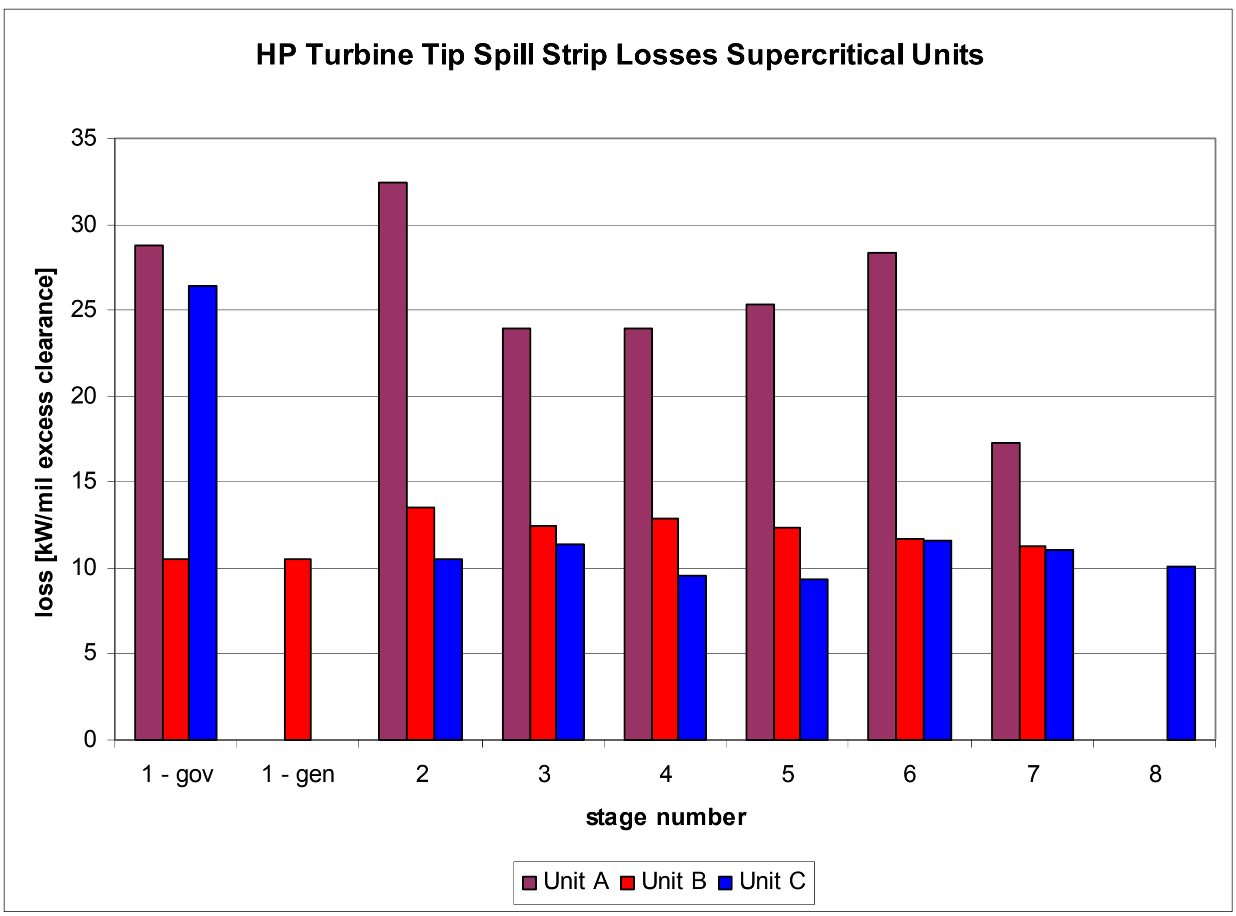
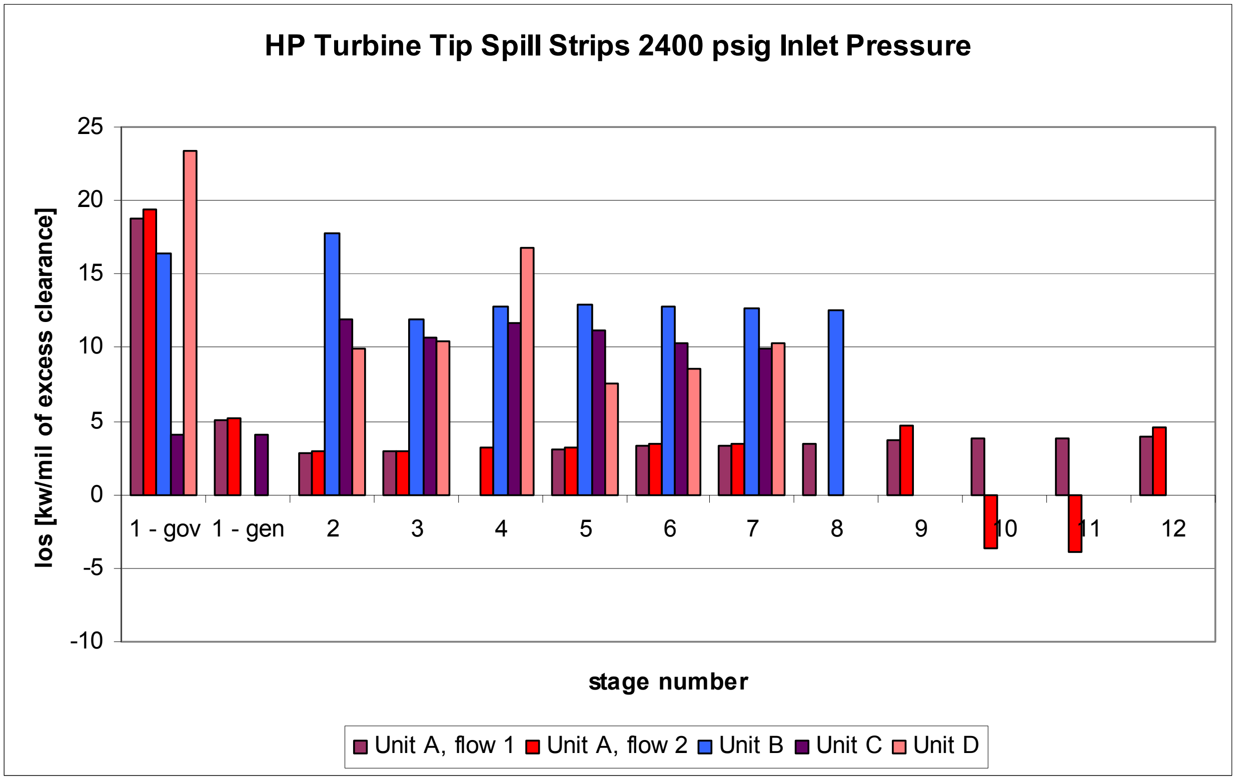


Figure 6



As can be seen there is significant variation in the loss/mil of excess clearance, and no clearly defined pattern.

Conclusion

There are a number of important conclusions that surface from this review of turbine leakage control devices:

1) First and foremost, wear or damage to these devices can impose significant:
   a) Reductions in the power that can be generated when running at VWO conditions
   b) Increases in the plant heat rate, or amount of fuel required to meet a specific load.
2) Obtaining accurate answers for the various losses requires the use of a sophisticated computer program that is designed specifically for this purpose and has been tested by use on a large number of steam path audits, about 150 in the case of Encotech's eSTPE program.
3) Use of incorrect audit loses can result in spending money to fix items that don't need it and failing to repair items that are severely degrading the turbine performance.