

>> STEAM AND CONDENSATE SYSTEM LEAKAGE COSTS

Steam and condensate leaks are unacceptable—and even abnormal—in today's industrial steam and condensate systems. These leaks cost industrial plants millions of dollars in lost energy while increasing emissions, creating safety hazards, and lowering the reliability of plant operations. Therefore, one of the highest returns on a plant's



Figure 1: Steam Leakage

investment is correcting steam and condensate leakage and instituting operational changes to prevent any leakage from occurring again in the system.

The steam leak shown in Figure 1 has the following effects:

- Energy loss: \$26,935.00 per year
- Emissions: 597,979 CO2 lbs. per year and 470 NOX lbs. per year
- Safety issue
- Reliability: a plant shutdown will have to occur to correct the leak
- Cost of steam: \$6.25 per 1,000 lbs., operating 350 days a year, with a 75 psig steam pressure

Steam and condensate leakage is one of the top five

opportunities for reducing energy and increasing reliability and safety in plant operations. Steam leaks result in the loss of both latent and sensible energy, while condensate leakage can be the loss of flash steam (latent and sensible energy) or just condensate, which is the loss of sensible energy. These losses add up—often to as much as 9% of overall energy consumption.

In fact, due to the high cost of these energy losses, the correction of steam and condensate leakage offers very lucrative paybacks. The greatest benefit of a proactive steam and condensate leakage correction program is that most leaks can be corrected without expending capital.

1. EXAMPLES OF ENERGY LOSSES

The following are examples of the energy losses from different steam leaks. Typically, threaded connections, which have the highest failure rate, will have the highest volume of steam passing to the atmosphere. Steam passing through the leakage point of threaded connections will



Figure 2: Steam Leak \$12,434.00 per Year



increase in volume due to the wiredrawing effect.

Standard valve packing is second in volume of steam loss to the atmosphere, because of the older technology in valve packing and because the packing area can be sizable.

The steam leak shown in Figure 2 has the	
following effects:	

Steam cost per 1,000 lbs.	\$6.25
Steam pressure	50
Steam loss (pph)	237
Cost/hour	\$1.48
Days/year	350
Cost/year	\$12,434.05
CO ₂ emissions/year	274,667
NO _x emissions/year	216
Safety issue	Yes
Shutdown required for correction	Yes



Figure 3: Steam Valve Leak \$3,585.00

The leak shown in Figure 3 has the following effects:	
Steam cost per 1,000 lbs.	\$5.20
Steam pressure	75
Steam loss (pph)	82
Cost/hour	\$0.43

Days/year	350
Cost/year	\$3,585.00
CO ₂ emissions/year	96,677
NO _x emissions/year	75
Safety issue	Yes
Shutdown required for correction	Yes



Figure 4: Steam Leak \$12,434.00 per Year

The steam leak shown in **Figure 4** has the following effects:

Steam cost per 1,000 lbs.	\$5.50
Steam pressure	45
Steam loss (pph)	491
Cost/hour	\$2.70
Days/year	350
Cost/year	\$22,716.00
CO ₂ emissions/year	569,504
NO _x emissions/year	448
Safety issue	Yes
Shutdown required for correction	Yes

The **TOTAL RESULTS** from the three leakage points in the steam system are as follows:

Steam loss (pph)	810
Cost/hour	\$4.61
Cost/year	\$38,735.05
CO ₂ emissions/year	940,848
NO _x emissions/year	739

That's \$38,735.00 per year for just three steam leaks. By making the necessary changes to the system, including updating to today's technology, steam and condensate leakage can be eliminated.

2. HOW TO DETERMINE LOSSES FROM STEAM LEAKS

Napier's equation is a well-accepted method for determining the leakage rate. However, most forms of the equation that are used in industry are very aggressive many times too aggressive. The standard formula is based on the orifice being "converging" and "well-rounded." This is rarely the case unless it is a steam trap orifice or a fullbore ball valve—as examples—that are discharging to the atmosphere.

Through its research and testing, Inveno Engineering has found that by adding a constant to the Napier orifice equation, it can estimate a conservative steam flow and energy loss from steam leaks.

Estimating Steam Loss: Napier's Equation

Steam Loss = $22.88 \times Pa \times D^2$

Where: 22.88 is a constant

Pa (Pressure differential absolute)

D² (Diameter squared)

Steam flow through a leak can be calculated using a the above orifice equation, which is based on the diameter of the leak, the pressure at the inlet of the orifice, and the pressure at the outlet (atmosphere).



Figure 5: Steam Flow

1. The leak path is not a perfect orifice.

 Determining the diameter of the passage is difficult because the leak is not a perfect circle.
Pressure at P1 may not be measured or indicated and may have to be calculated based on methods.



Figure 6: Pressure Upstream and Downstream of a Leak

Our upstream pressure and P2 (outlet pressure) will be 0 psig because the steam and condensate leaks are discharging to the atmosphere.

There are many variables in determining the cost for steam and condensate leakage, such as the following:

- the true diameter of the leakage passage,
- the correct steam or condensate pressure at P1,
- the restrictions that could affect P1 pressure:



for example, a steam leak on the outlet of the valve (calculate the pressure drop in the valve to determine P1), and

• leakage around valve packing or threaded connections.

If a pressure measurement or indication is not available for P1 and the steam is saturated, then the task of determining P1 is accomplished easily by using an infrared temperature measurement device. Saturated steam at a given temperature directly correlates to saturated steam pressure.

All factors must be considered when estimating the true cost of the steam and condensate loss.

Steam flow through a leak can be calculated using an orifice equation, which is based on the diameter of the leak, the pressure at the inlet of the orifice, and the pressure at the outlet (atmosphere).

2.1. How to Determine the Diameter of the Leak Path

Even for the most experienced plant personnel, determining the diameter of the leak path is difficult at best. Steam is extremely hot, and trying to measure the diameter of the path can be dangerous. Many times, the actual leak cannot be observed due to insulation or other factors.

Leaks can occur in the packing around a control



Figure 7: Estimating Leak Volume by Plume Length

valve stem, a union connection, a flange connection, etc. It is definitely not always easy to determine the actual size of the orifice (hole). Inveno Engineering recommends that plant personnel be trained with different tools to help visually determine the steam leak diameter from a safe distance.

Note: Using high-frequency ultrasound has been extremely helpful in determining the leakage volume, but the personnel using the equipment need to be trained on how to accomplish this goal.

Determining the steam leak volume by plume length is extremely difficult and is not very accurate.

3. ROAD MAP FOR STEAM LEAKAGE

Changes need to occur imminently to achieve a leak-free steam and condensate system. The goal of a leak-free system is achievable with the correct changes.