

Procedure for Flow Induced Vibration Calculations



Overview

This guide provides instructions on how to use the calculation spreadsheet created based on the Energy Institute's "Guidelines for the Avoidance of Vibration Induced Fatigue Failure in Process Pipework," which provide a procedure to calculate a likelihood of failure (LOF) for different vibration based on different vibration mechanisms that can be used to adjust the system design to prevent fatigue.

Background

There are a variety of piping vibration sources which engineers should analyze in their systems. AFT Impulse PFA can be used to analyze acoustical excitation and pulsation caused by reciprocating pumps. Base AFT Impulse can also be used to address cavitation and surge issues, which can contribute to vibration in the system. AFT xStream PFA is intended to address acoustical excitation and vibration caused by reciprocating compressors. AFT xStream may also be able to help troubleshoot rotating stall in centrifugal compressors, which can be another source of vibration.

Beyond the vibration sources described above, this spreadsheet is intended to address the following vibration sources:

- Flow Induced Vibration (FIV)
 - Occurs in both compressible and incompressible flow. Excitation caused by turbulence in the flow, which is primarily experienced at discontinuities like partially closed valves, bends, tees, reducers, etc. Generally, this type of excitation is concentrated at low frequencies (< 100 Hz) and can lead to visible vibrations of the piping and pipe supports.
- Pulsation: Flow Induced Excitation (FIP)
 - In gas systems flow past a branch with a dead end, or flow around a component inserted in the flow stream can cause vortices to form. On their own they are typically not damaging, but if they coincide with an acoustic or structural natural frequency, then high levels of pulsation can occur. Only the mechanism for flow past dead ends is covered by the EI guidelines.
- High Frequency Acoustic Excitation (AIV)
 - In gas systems significant pressure loss sources such as control valves, relief valves, etc. can generate high frequency acoustic energy which is damaging due to the noise output as well as the vibration of the pipe walls. This can affect pipe supports and connections as well. Typically, frequencies are in the range of 500 – 2000 Hz.

Flow Induced Vibration (FIV)

Reference: Pages 48-53, Section T2.2, Flowchart T2-1

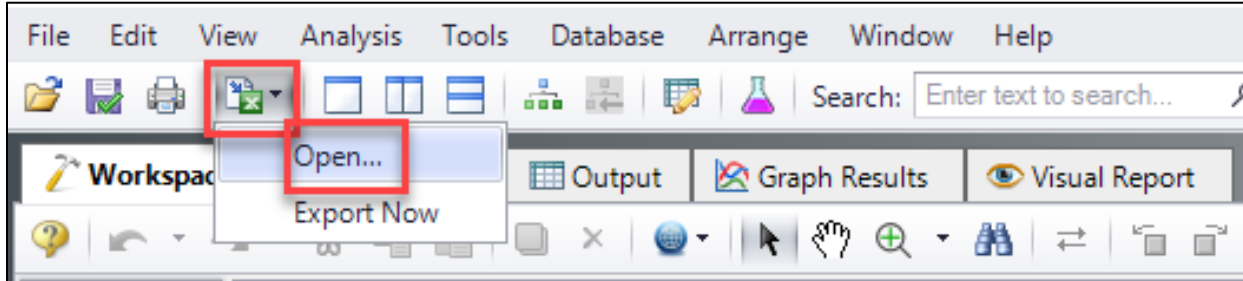
Purpose: Determine main line LOF based on turbulence in main line

Input Sources/Descriptions:

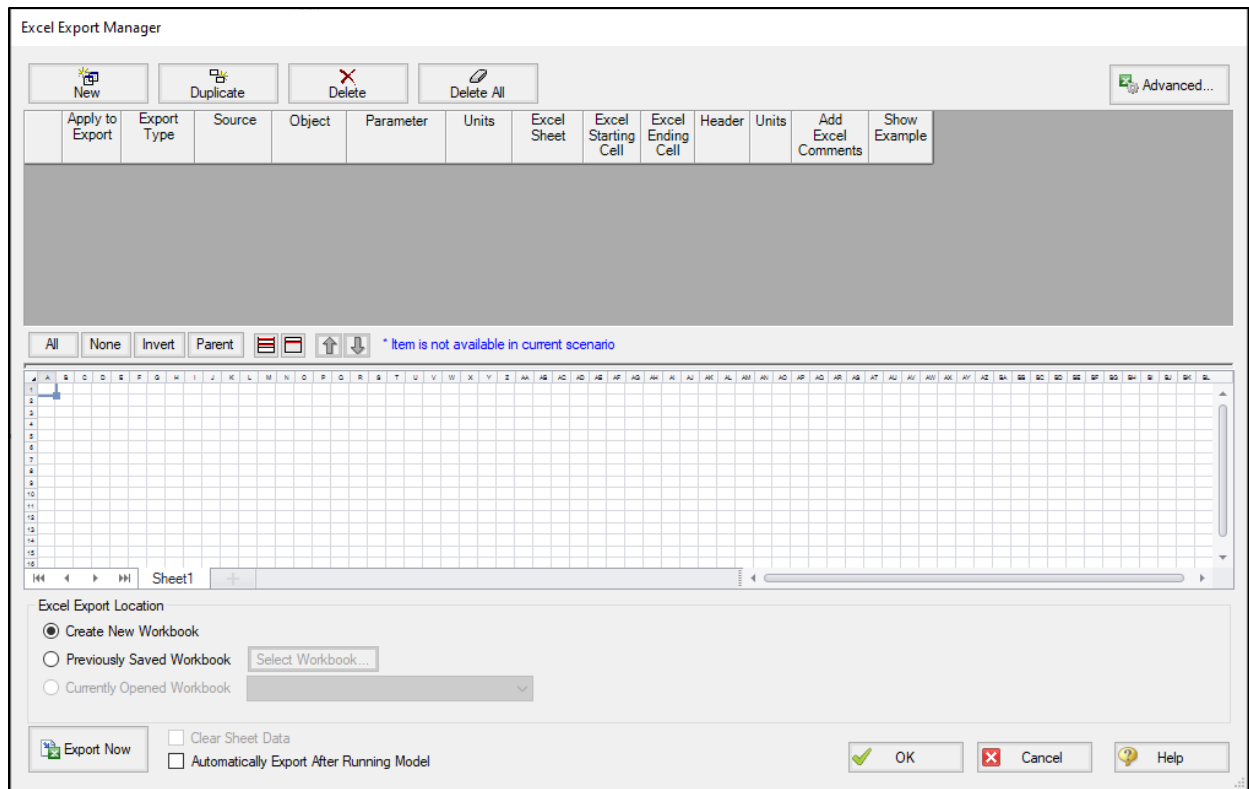
Inputs	Source	Description
L,span	User Input	Max span length between supports
T	User Input	Thickness of pipe wall
fn (adv. only)	User Input	Structural natural frequencies
D,int	AFT Export	Internal pipe diameter
ρ	AFT Export	Fluid density (static)
v	AFT Export	Fluid velocity
μ (gas only)	AFT Export	Dynamic viscosity

Procedure:

1. Run the model to get results.
2. Determine the pipe to be analyzed for Flow Induced Turbulence.
3. From the Workspace, click the **Excel Export Manager** button on the toolbar, then click **Open**.



4. The blank Excel Export Manager window appears.



5. With the Excel Export Manager open, click **New** to add a row, then input the following into rows using the images below the table as a guide based on the fluid type.

- P# (Pipe) shall be the same pipe for all rows.
- Units shall be the same as shown in the table

a. For incompressible fluids:

Object	Parameter	Units	Excel Sheet	Excel Starting Cell	Header	Units
P# (Pipe)	Diameter Hydraulic	mm	FIV Calcs Liquid	C13	<input type="checkbox"/>	<input type="checkbox"/>
P# (Pipe)	Density of Fluid Average	kg/m3	FIV Calcs Liquid	C14	<input type="checkbox"/>	<input type="checkbox"/>
P# (Pipe)	Velocity	meters/sec	FIV Calcs Liquid	C15	<input type="checkbox"/>	<input type="checkbox"/>

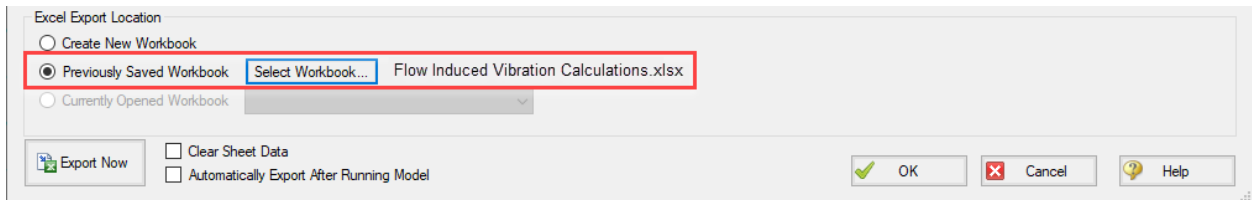
b. For compressible fluids:

Object	Parameter	Units	Excel Sheet	Excel Starting Cell	Header	Units
P# (Pipe)	Diameter Hydraulic	mm	FIV Calcs Gas	C13	<input type="checkbox"/>	<input type="checkbox"/>
P# (Pipe)	Density Static Inlet	kg/m3	FIV Calcs Gas	C14	<input type="checkbox"/>	<input type="checkbox"/>
P# (Pipe)	Velocity Inlet	meters/sec	FIV Calcs Gas	C15	<input type="checkbox"/>	<input type="checkbox"/>
P# (Pipe)	Viscosity Inlet	Pa-sec	FIV Calcs Gas	C16	<input type="checkbox"/>	<input type="checkbox"/>

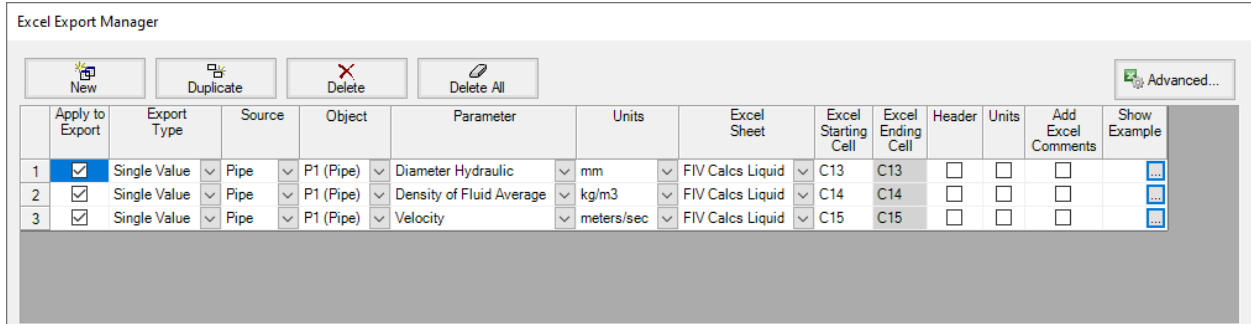
6. At the bottom, for Excel Export Location, click the radio button for **Previously Saved Workbook**.

7. Click the **Select Workbook** button, navigate to the **Flow Induced Vibration Calculation.xlsx** file then click **Open**.

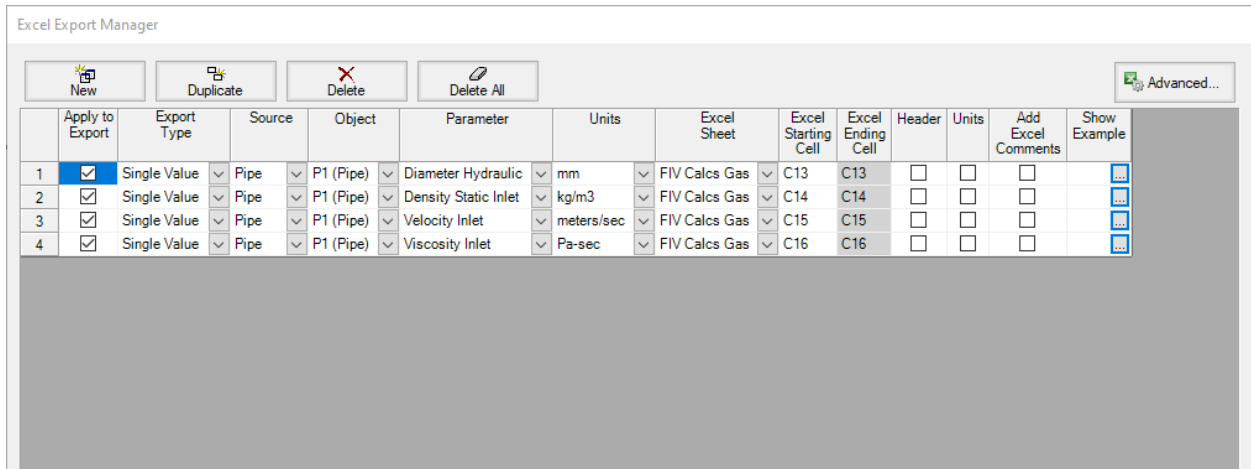
8. The bottom of the Excel Export Manager window should look like the following image:



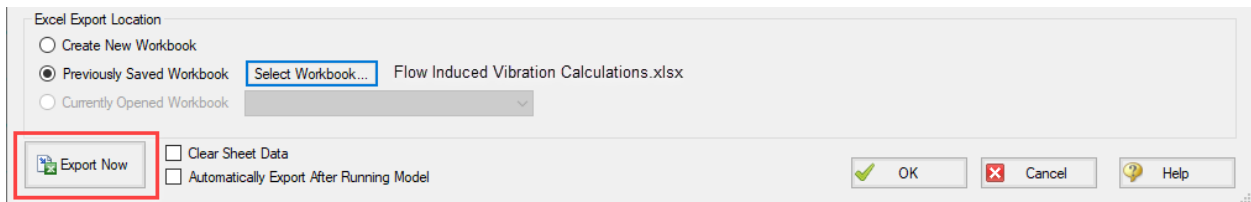
9. The Excel Export Manager window should look like the following:
 - a. For incompressible fluids:



- b. For compressible fluids:



10. Double check that the same pipe is selected for all rows, the Parameters, Units, Excel Sheet, Excel Starting Cells, the Header and Units checkboxes all match the above window, and the **Flow Induced Vibration Calculation.xlsx** is the workbook for the Previously Saved Workbook.
11. Once all inputs are confirmed to match the above window, click **Export Now** at the bottom left:



12. AFT Fathom will export the parameters to the spreadsheet which has the prebuilt calculations.

See Flow Induced Turbulence Vibrations (FIV) procedure for instructions on how to use this spreadsheet

The equations and methodology used here are from "Guidelines for the Avoidance of Vibration Induced Fatigue Failure in Process Pipework" Section T 2.2. This workbook is intended for use by authorized users of the above guidelines. See the EI website for more information or to purchase the guidelines: <https://publishing.energyinst.org/topics/asset-integrity/guidelines-for-the-avoidance-of-vibration-induced-fatigue-failure-in-process-pipework>

Inputs		
L,span	5	m
T	5.5	mm
fn (adv. only)	1.0	Hz
D,int	77.93	mm
ρ	998	kg/m ³
v	2.27	m/s

Key	
Orange	User Input
Yellow	AFT Export
Light Blue	Result

Output	
LOF	0.267

13. With the values from AFT Fathom, enter the user specified values for the remaining inputs:

- L,span in m
- T in mm
- fn (advanced only)
 - For the highest accuracy, the natural frequency should be measured for the system.
 - If the natural frequency is not known the typical fundamental natural frequency for the system based on the support type is given in Table T2-1 on page 50 of the EI Guidelines and is shown in the spreadsheet in the "Determining Support Type" table in cells F28-F31.

14. The LOF is calculated and shown in cell C19 in the output section.

15. Use the EI Guidelines to determine appropriate actions based on displayed LOF.

Pulsation: Flow Induced Excitation (FIP)

Reference: Pages 57-58, Section T2.6, Flowchart T2-4

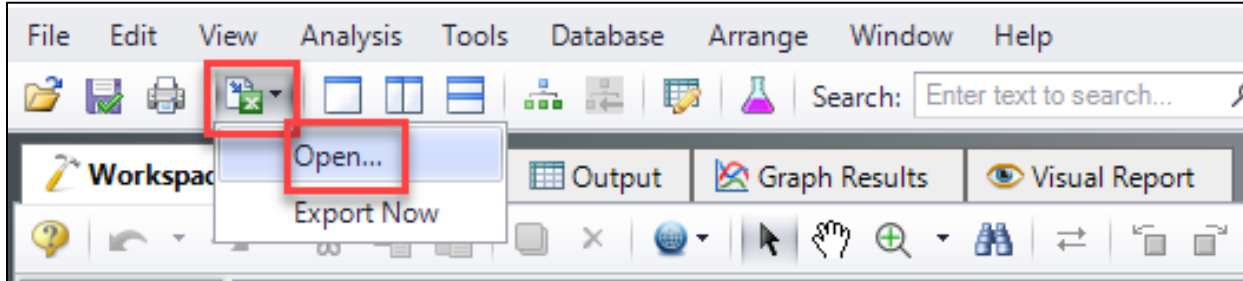
Purpose: Determine LOF for main line based on deadleg branch calculations

Input Sources/Descriptions:

Inputs	Source	Description
c	AFT Export	Sonic velocity at branching point
d,int	AFT Export	Internal diameter branch
D,int	AFT Export	Internal diameter main line
L,branch	AFT Export	Length branch
Re	AFT Export	Re at branching point
v	AFT Export	Velocity at branching point
ρ	AFT Export	Gas density in main line (static)

Procedure:

1. Run the model to get results.
2. Determine the dead-leg branch to be analyzed for Flow Induced Excitation.
3. From the Workspace, click the **Excel Export Manager** button on the toolbar, then click **Open**.



4. The blank Excel Export Manager window appears.

Excel Export Manager

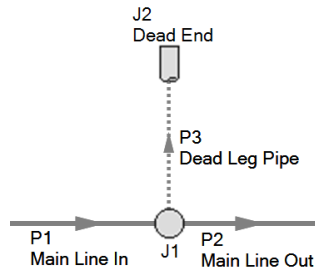
Apply to Export	Export Type	Source	Object	Parameter	Units	Excel Sheet	Excel Starting Cell	Excel Ending Cell	Header	Units	Add Excel Comments	Show Example

* Item is not available in current scenario

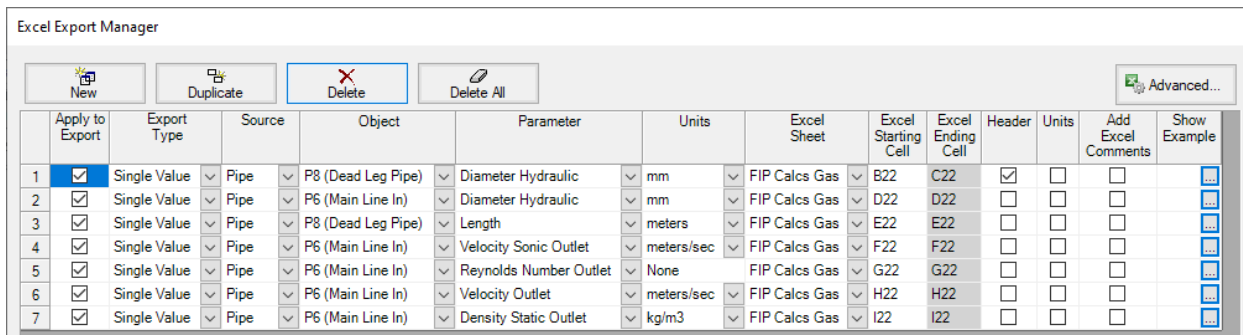
Clear Sheet Data
 Automatically Export After Running Model

- With the Excel Export Manager open, click **New** to add a row, then input the following into seven rows using the image below the table as a guide for pipes:

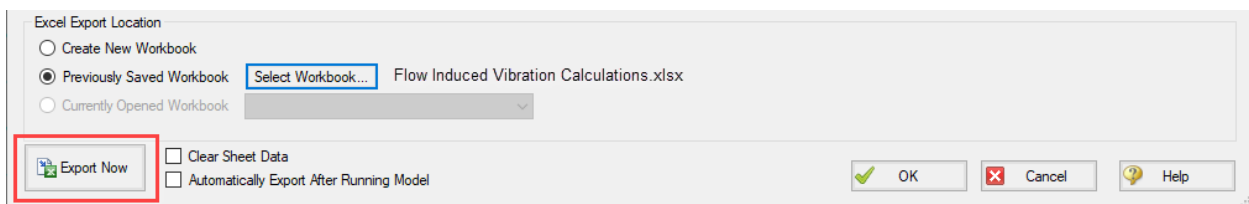
Object	Parameter	Units	Excel Sheet	Excel Starting Cell	Header	Units
Dead Leg Pipe	Diameter Hydraulic	mm	FIP Calcs Gas	B22	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Main Line In	Diameter Hydraulic	mm	FIP Calcs Gas	D22	<input type="checkbox"/>	<input type="checkbox"/>
Dead Leg Pipe	Length	meters	FIP Calcs Gas	E22	<input type="checkbox"/>	<input type="checkbox"/>
Main Line In	Velocity Sonic Outlet	meters/sec	FIP Calcs Gas	F22	<input type="checkbox"/>	<input type="checkbox"/>
Main Line In	Reynolds Number Outlet	None	FIP Calcs Gas	G22	<input type="checkbox"/>	<input type="checkbox"/>
Main Line In	Velocity Outlet	meters/sec	FIP Calcs Gas	H22	<input type="checkbox"/>	<input type="checkbox"/>
Main Line In	Density Static Outlet	kg/m3	FIP Calcs Gas	I22	<input type="checkbox"/>	<input type="checkbox"/>



- At the bottom, for Excel Export Location, click the radio button for **Previously Saved Workbook**.
- Click the **Select Workbook** button, navigate to the **Flow Induced Vibration Calculation.xlsx** file.
- The Excel Export Manager window should look like the following:



- Once all inputs are confirmed to match the above window, click **Export Now** at the bottom left.



10. AFT Arrow will export the parameters to the spreadsheet which has the prebuilt calculations.

See Pulsation: Flow Induced Excitation (FIP) procedure for instructions on how to use this spreadsheet

The equations and methodology used here are from "Guidelines for the Avoidance of Vibration Induced Fatigue Failure in Process Pipework" Section T 2.6. This workbook is intended for use by authorized users of the above guidelines. See the EI website for more information or to purchase the guidelines: <https://publishing.energyinst.org/topics/asset-integrity/guidelines-for-the-avoidance-of-vibration-induced-fatigue-failure-in-process-pipework>

LOF Main Branch	1															
Input Descriptions	Key															
c	Sonic velocity at branching point															
d,int	Internal diameter branch															
D,int	Internal diameter main line															
L,branch	Length branch															
Re	Re at branching point															
v	Velocity at branching point															
p	Gas density in main line (static)															
Dead-end	d,int	D,int	L,branch	c	Re	v	p	d,int/D,int	d,crit	d,int < d,crit? S (Re>1.6E7)	S1 (Re<1.6E7)	S	Fv	Fs	LOF	
P8 (Pipe) Hyd. Diameter	52.5018	154.051	0.1524	357.8094	11,020,382.	95.2916	5,6499	0.34	49.82	No	0.332	0.285	0.285	518.026	483.653	1

11. Repeat the steps above for other branches by exporting the values to the next open row.
12. The LOF for each dead end will be calculated and shown in column R.
13. The LOF for the main branch will be equivalent to the highest branch LOF, shown in cell D9.
14. Use the EI Guidelines to determine appropriate actions based on displayed LOF.

High Frequency Acoustic Excitation (AIV)

Reference: Pages 59-62, Section T2.7, Flowcharts T2-5 and T2-6

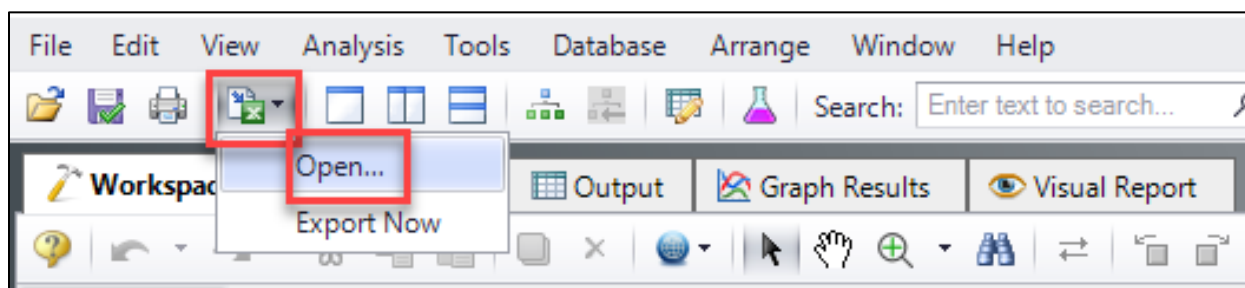
Purpose: Determine the LOF in the main line based on high frequency sources (control valves, relief valves, etc)

Input description:

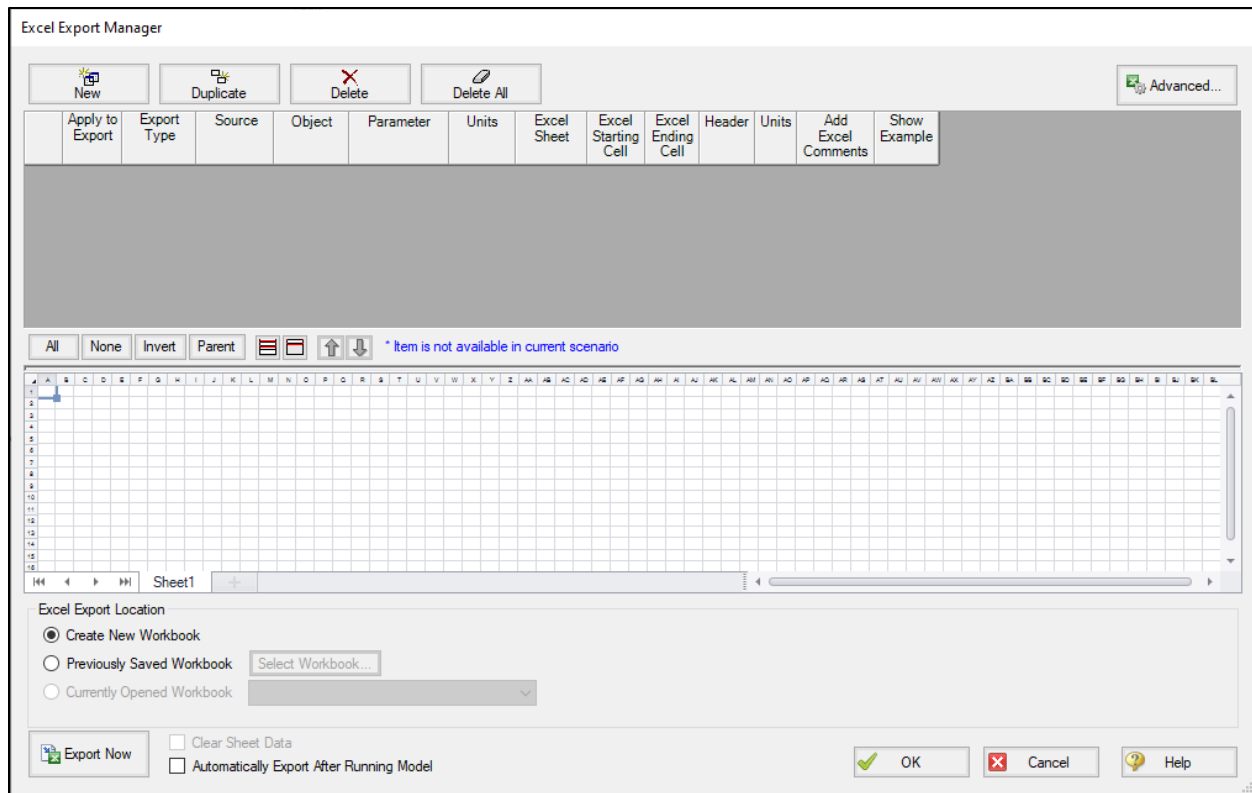
Inputs	Calculation	Source	Description
Low Noise Trim	Sources	User Input	Reduction in sound level due to low noise valve trim
Mw	Sources	User Input	Molecular weight
d,ext	Discontinuities	User Input	Branch external diameter
L,dis	Discontinuities	User Input	Distance from source to discontinuity
Piping Material	Discontinuities	User Input	Y if piping material is duplex, N if not
T	Discontinuities	User Input	Wall thickness main line
Weldolet	Discontinuities	User Input	Y if discontinuity is weldolet type fitting or N if not
P1	Sources	AFT Export	Pressure upstream of device
P2	Sources	AFT Export	Pressure downstream of device
Te	Sources	AFT Export	Upstream temperature
W	Sources	AFT Export	Mass flowrate
D,int	Discontinuities	AFT Export	Main line internal diameter

Procedure:

1. Run the model to get results.
2. Determine the first source in the line to be analyzed for High Frequency Acoustic Excitation.
3. From the Workspace, click the **Excel Export Manager** button on the toolbar, then click **Open**.



4. The blank Excel Export Manager window appears.



- With the Excel Export Manager open, click **New** to add a row, then input the following into four rows using the image below the table as a guide for pipes:

Source	Object	Parameter	Units	Excel Sheet	Excel Starting Cell
Junction	J#	Pressure Stagnation Inlet	Pascals	AIV Calcs	D18
Junction	J#	Pressure Stagnation Outlet	Pascals	AIV Calcs	E18
Pipe	Upstream Pipe of J#	Temperature Static Outlet	deg. K	AIV Calcs	F18
Junction	J#	Mass Flow Rate Through Junction	kg/sec	AIV Calcs	G18

- Once all inputs are confirmed to match the above window, click **Export Now** at the bottom left.
- AFT Arrow will export the parameters to the AIV Calcs sheet which has the prebuilt calculations.
- In the sheet, manually enter the molecular weight and sonic choking status in cells D12 and D13 (skip if already entered).
- Manually enter the junction number into column C.
- Manually enter the sound level reduction Low Noise Trim (dB) parameter in column H if present.
- Check the PWL value in column I:
 - If PWL is less than 155 dB, **then the calculation is finished**, check LOF in D9.
 - If PWL is greater than or equal to 155 dB, proceed to next step.

12. Find the next component in the line:
 - a. If the next component is an additional vibration source, repeat steps 5 through 11, but instead of using row 18 for columns D through G, use the next available row.
 - b. If the next component is a major vessel, **then the calculation is finished**, check LOF in D9.
 - c. If the next component is a discontinuity, proceed to next step.
13. In the spreadsheet, manually enter the inputs for the discontinuity in columns O through T.
14. For column N, export (or manually enter) Diameter Hydraulic in mm for the main line pipe upstream of the discontinuity. If this is the first discontinuity, export to N18, otherwise use the next available row in column N.
15. Check the PWL,disc value in column V:
 - a. If PWL,disc is less than 155 dB, **then the calculation is finished**, check LOF in D9.
 - b. If PWL,disc is greater than or equal to 155 dB, then repeat steps 12 through 15.