AIR TECHNOLOGY ENGINES, INC.

T53 Engineering Product Support Notice – Engine Starting

December 10, 2019

Engine starting can be the most destructive operation of a turbine engine. Engine manufacturers use various means of controlling the starting fuel schedule. The most reliable is with metered fuel. The T53 series uses metered fuel for the main fuel nozzles and unmetered fuel for the starting fuel nozzles. The best starting procedure is with fuel turned off and when an engine reaches a certain speed, to turn on metered fuel that has a minimum and maximum fuel flow at each percent speed. In addition, the T53 uses four unmetered starting fuel nozzles with better atomization than the main fuel nozzles at low N1 speeds. At approximately 25% N1, the atomization of the main fuel nozzles primaries is better than the atomization of the starting fuel nozzles.

When the starting fuel nozzles are kept on above 25% N1, the atomization of the main fuel nozzles is degraded and carbon balls occur that damage the turbine blades. Instead of helping the engine to start, the four starting nozzles become torches that can and will damage the vanes in the 1st and 2nd Gas Producer Nozzles. As the engine speed increases, the increased pressure drives the flames from the four starting nozzles into the gas producer nozzles. At slightly above 5% N1, metered atomized fuel begins to flow from primaries of the 22 main fuel nozzles and unmetered atomized fuel begins flowing from 4 starting fuel nozzles. That fuel is raw fuel and when it ignites it is likely to be burning in the turbine nozzles. Ignition usually occurs between 13% and 18% N1. When the fuel and ignition are turned on above 20% N1, the air velocity prevents the fuel from igniting.

The fuel flow at Ground Idle is 130 #Wf/hr. A gallon of jet fuel weighs 6.8#.

The following chart shows the amount of fuel being "fed" to the engine during starting:

Notes regarding Table.
Engine Ground Idle Fuel Flow at 50% N1 is 130 PPH
Use of Starting Fuel Nozzles above 25% N1 can result in burning of 1st and 2nd stage GP nozzle vanes. The starting fuel does not stay within their own cone and as engine speed increases, the starting fuel paths of burning disrupt the adjacent cones of burning primary fuel and the burning will extend into the GP nozzles.
Actual Engine Fuel Flows were Measured at Standard day conditions

% ENG RPM	Main Fuel Flow Metered (in PPH)	Starting Fuel Nozzles (in PPH)	Total Start Fuel with starting fuel nozzles (in PPH)	% Fuel Increase with starting nozzles on (in PPH)
5	0.0	26	26	
10	66	27	93	+ 41%
15	69	27.6	97	+ 40%
20	87	28.2	116	+32.4%
25	103	28.6	132 (same a s GI Fuel flow @ 50% N1)	+ 27.8%
30	120	29	149	+ 24.1%
35	144	29.3	173	+ 20.3%

Above 25% N1, the Air/Fuel ratio is below 50 to1 when the starting fuel nozzles are flowing fuel. When the A/F ratio falls below 50 to 1, intermittent combustion (also referred to as combustor rumble) occurs and will cause a hotter and even longer start.

There is a myth that fast starts are better for an engine. They are when good battery power creates faster engine spooling. This means appropriate induction of fuel causes less heat buildup with faster engine spooling due to starter speed, not speed (and heat) induced by excess fuel.

Cool starts are better for an engine. The starting fuel nozzles should never be held on past 25% N1 speed. Starting a turbine engine on a warm day is much easier on an engine than starting on a cold day. Starting on a cold day can take as much as twice as long as on a hot day (30 seconds vs 15 seconds). During a start, if the engine is trending towards maximum starting MGT/EGT, it would be wise to abort the start. After coast down, perform a cool down by motoring the engine (starting fuel and igniters off) to achieve an MGT/EGT reading below 150 degrees C. Restart the engine.

Just for information: If hot starting continues, check for faulty igniters, blocked starting fuel nozzles and coking in the starting fuel purge valve.