



Quicksilver GT-500 Preliminary Engine Tear-down Inspection Summary

Date of accident: 11-25-2017

N Number: N599RA

Airframe: S/N 151

Engine: Type Rotax 582 Blue Head (2 cylinder water cooled two stroke)

Engine: S/N 5438215

TSMOH: 297 (Unverified, best estimate from aircraft owner)

Last Annual: Dec 2016

Oil: Lucas semi synthetic

Gasoline: 50:1 pre-mix and regular gasoline

Report Prepared 12-31-2017 By: Brian Carpenter (Resume On file)

The aircraft was on the take-off segment of its third leg of a cross-country training flight when engine stoppage occurred. First leg from Corning, California to Oroville, California, second leg from Oroville, California to Willows, California, the third leg was to be from Willows, California back to Corning, California.

Ref: Supporting video and audio:

Approximately 45 minutes had elapsed from the engine shut down after arrival at the Willows Airport until the start of the video. Time stamp 00:00:00:00

Time Stamp:

03:28:04 Engine start.

06:25:55 Run-up commences. Run-up RPM approximately 3000 RPM.

06:37:18 End of Run-Up. Total Run up time approximately 12 to 13 seconds.

07:39:07 Application of power for the beginning of the takeoff run.

07:54:12 First indication of power plant failure. (Pre-ignition/Detonation).

07:57:04 First indication of cylinder/piston seizure.

08:01:21 Engine stoppage occurs.

08:07:05 First impact with the ground. Video stops, Audio Continues.

Engine Inspection:

A step-by-step inspection has been conducted of the power-plant assembly. Included within this PDF document are thumbnail pictures to help guide the narrative. Full-size photographs accompany this document for closer scrutiny. The majority of the photographs used for this project were shot with a Canon EOS 5D Mark IV at a 30 mega-pixel resolution shot in raw format. The majority of close-up shots were taken using a 24-70 mm f1-2.8 macro lens and have been post-processed using a process called photo stacking. This allows for high resolution with a unlimited depth of field.

The discrepancies pertinent to the failure of the engine are as follows:

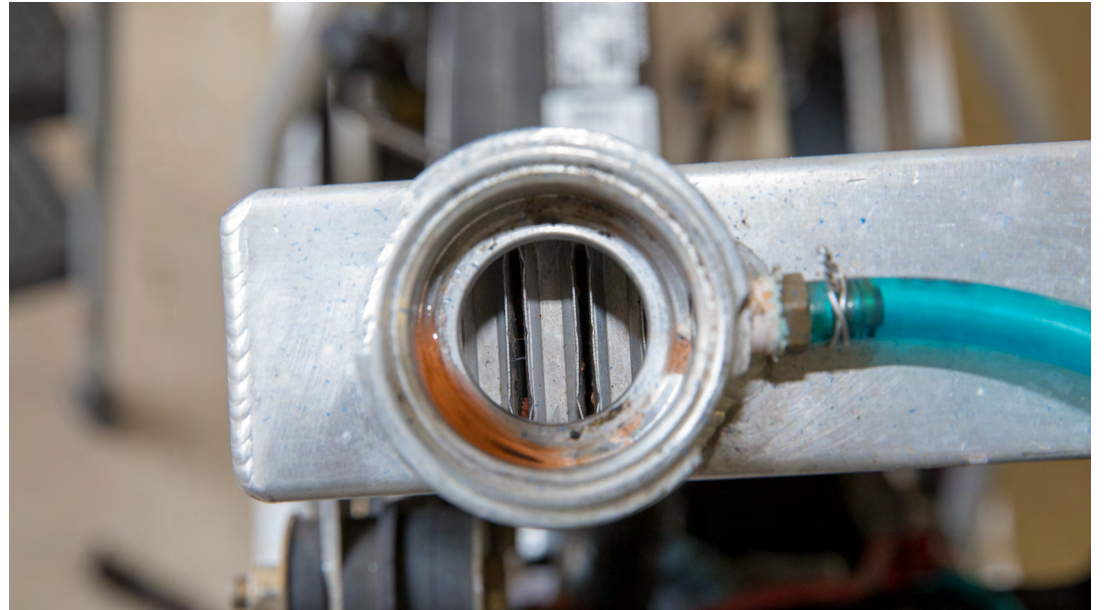


Figure: 1 Radiator

1. Radiator: Radiator coolant level was found to be low enough that the fluid was not be visible through the radiator cap. (Figure: 1) There was antifreeze in the system. After draining the remaining coolant from the system, it is estimated that approximately 1/4 of the antifreeze was missing from the cooling system.
2. Coolant recovery bottle: The radiator overflow and recovery bottle had fluid in the bottle. The amount of

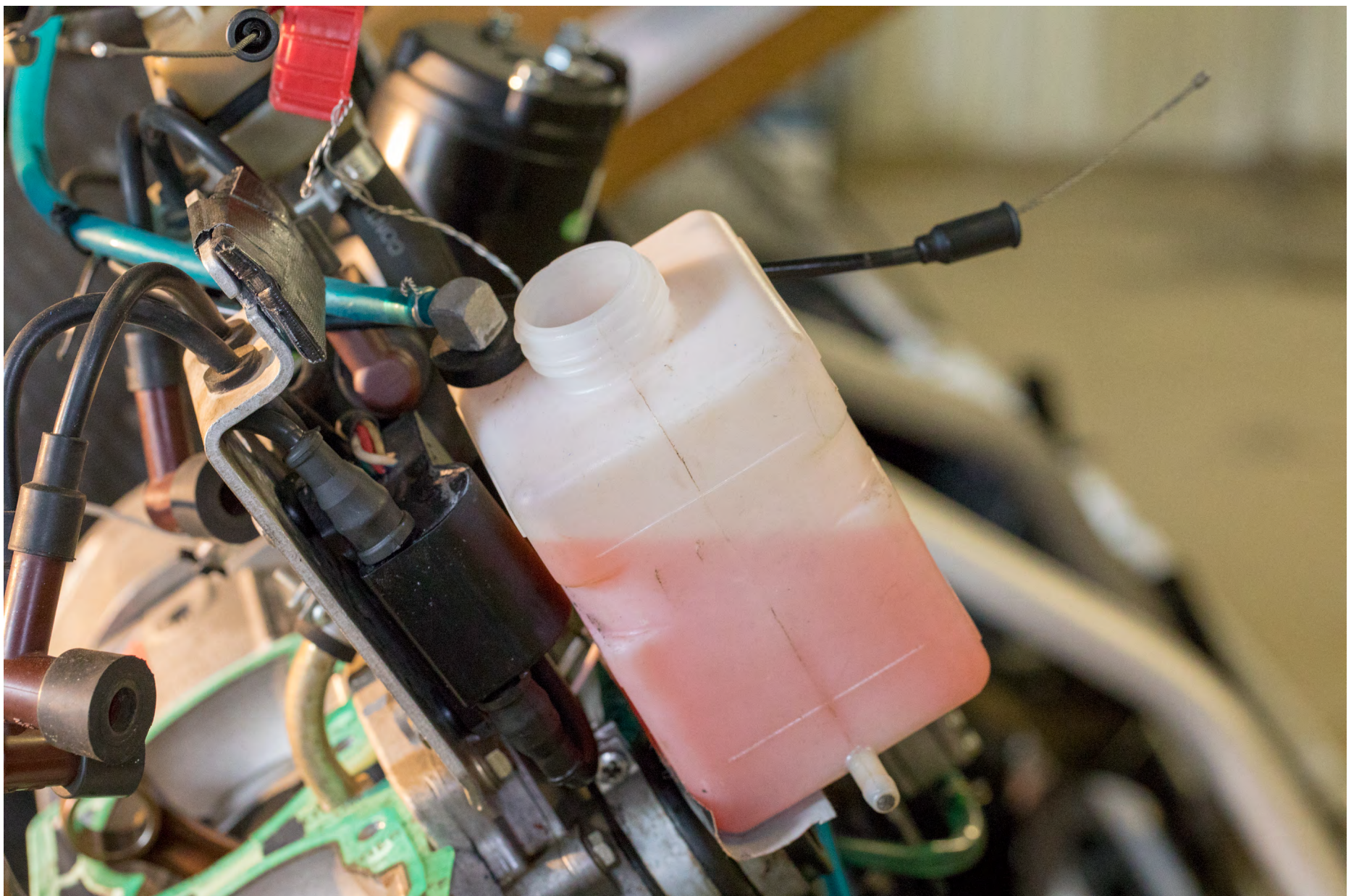


Figure: 2 Radiator Overflow and Recovery Bottle



Figure: 3 Water Pump

coolant in the bottle was within normal servicing limits.(Figure: 2) However, the recovery bottle was rendered nonfunctional by the improper installation. The hose from the radiator is attached to the top of the recovery bottle rather than its proper location which would be at the bottom of the recovery bottle. The 90° fitting installed into the top of the recovery bottle extends into the bottle less than 1 inch. Any loss of fluid in between any flights could not be replenished during the cool-down cycle. The normal nipple used for installation has been plugged.

3. Water pump: The water pump system was intact and operating correctly. No physical signs of looseness or play in the water pump shaft. (Figure: 3)
4. Coolant Leak: A small, but visible, leak was found on the water pump inlet hose, (Figure: 4) water pump housing, case halves, and motor mount plate on the exhaust side of the engine. The exhaust side is also the side that the water pump and coolant hoses are mounted on. No leaks or discharge from the radiator were evident. One of the more common sources of leaks on this side of the engine is at the case half location directly underneath the water pump. (Figure: 5) There is a witness hole that will drain coolant if the Rotary intake valve shaft seal leaks coolant. The Rotary intake valve shaft is also the shaft that drives the water pump. On earlier versions of the Rotax 582 this was a common problem area with frequent leaks, however, on the blue head 582, the problems were addressed in a design change and the number of shaft seal leaks have now diminished and this problem is now considered rare. Close examination of this area between the case halves and underneath the water pump revealed that there is coolant in this area. However, there is a strong possibility that the fluid leak around the water pump housing nipple, Located directly above, is the source of this fluid. Because of the relatively small amounts of fluid that leak through this shaft seal, past experience has shown that visual inspection of the seals when removed from the engine is not an adequate method of determining whether or not the seals are functioning properly. A visual indication of fluid leaking or not leaking at the weep hole is the best indication of the seals condition. And because we cannot run the engine after repairing the hose leak without first repairing the engine, the possibility of the shaft seals contribution to the leak remains unknown.
5. Water pump housing nipple: Looking at the water pump housing nipple (Figure: 6) We can see coolant, mixed with caked on debris, that has obviously accumulated over a period of time. The majority of this

accumulation is on the top of the water pump housing nipple. And the water pump housing is located above the case halves. Because there are no other sources for coolant in this general vicinity the most likely source of the leak are these hoses and nipples on the water pump housing. Upon closer examination of the water pump housing nipple we can see that the casting has some anomalies. (Figure: 6) we can see a step in the casting. We find this typical of other 582 engines as well and the normal remedy would be to simply rework this area to create a smooth surface for hose installation. However, in (Figure: 7) we see an example on the outside casting seam with a more extreme step. In this case, it appears as though this would be rather difficult to completely eliminate a leak without a significant degree of rework or replacement of the housing. Based on the evidence of excessive tightening of both hose clamps in this location, it would be reasonable to suspect that previous evidence of leakage was identified and attempts made to remedy the situation with ex-



Figure: 4 Hose leak at Water Pump Housing

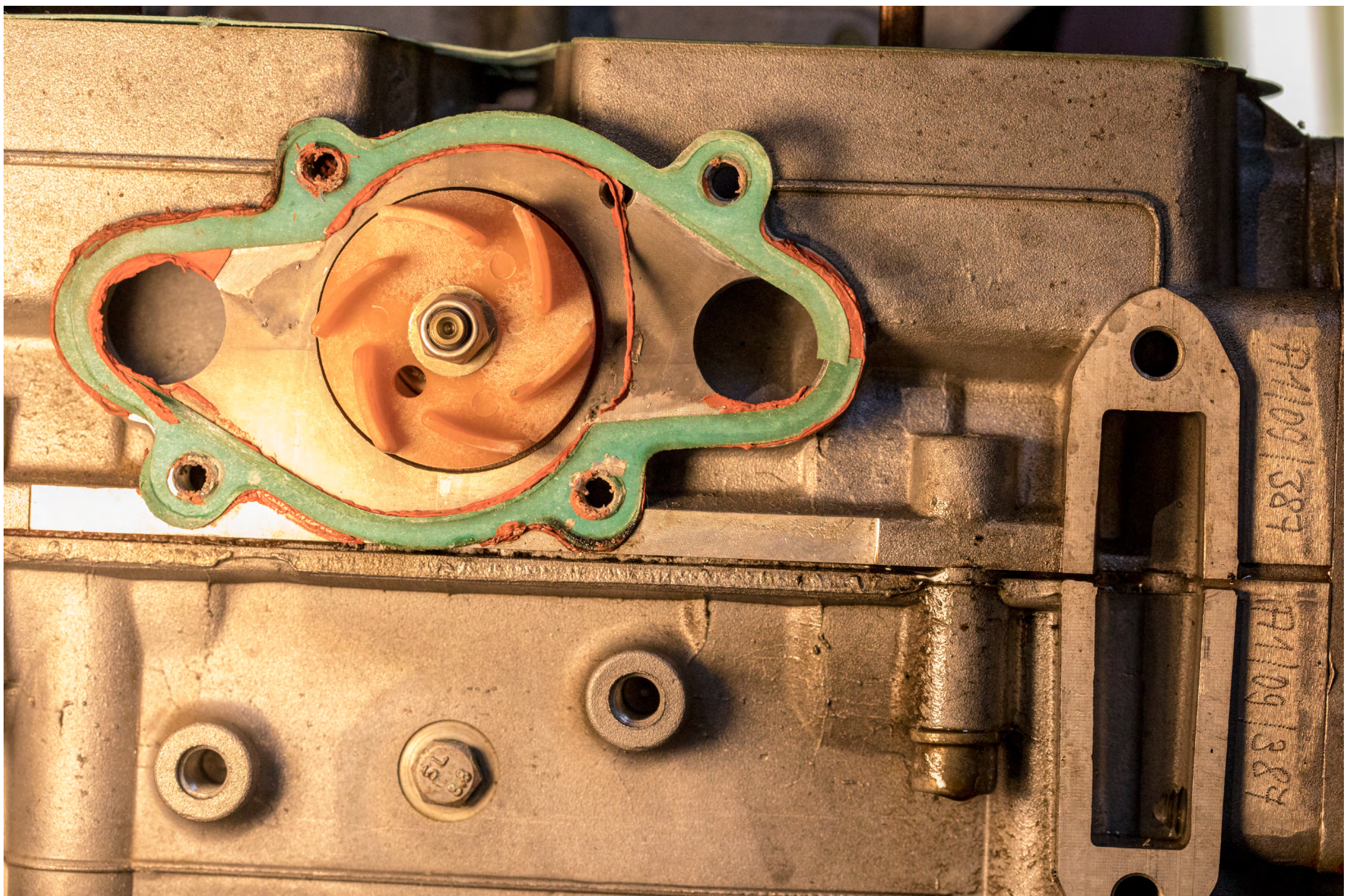


Figure: 5 Case Halves



Figure: 6 Water Pump Housing Nipple (Inner)

cessive tightening of the hose clamps. The hose was removed and measured at 1 inch ID and the water pump housing nipple (not concentric) was measured at .904 inches at its smallest dimension and .978 at its largest dimension. Based on these anomalies, it is likely that this is at least, the primary source of fluid loss within the coolant system.



Figure: 7 Water Pump Housing Nipple (Outer)



Figure: 8 PTO Clyinder

6. Inspection of both cylinders show signs of lack of coolant. In (Figure: 8) you can see the walls of the water jacket on the exhaust port side are dry. Whereas, on the intake port side (cool side of the cylinder), there are signs of anti-freeze still embedded into the surface of the aluminum cylinders. This over heating indication is evident on both the PTO and the Magneto cylinders. The PTO cylinder shows the same symptoms as the magneto cylinder which suffered the seizure. However, this cylinder did not suffer any catastrophic failure.
7. Spark plugs (magneto side): Melting of both spark plug electrodes on the magneto cylinder is an indication of pre-ignition and subsequent detonation within that cylinder. (Figure: 9) shown is the plug closest to the magneto with the greatest amount of degradation.



Figure: 9 Magneto Side Spark Plug

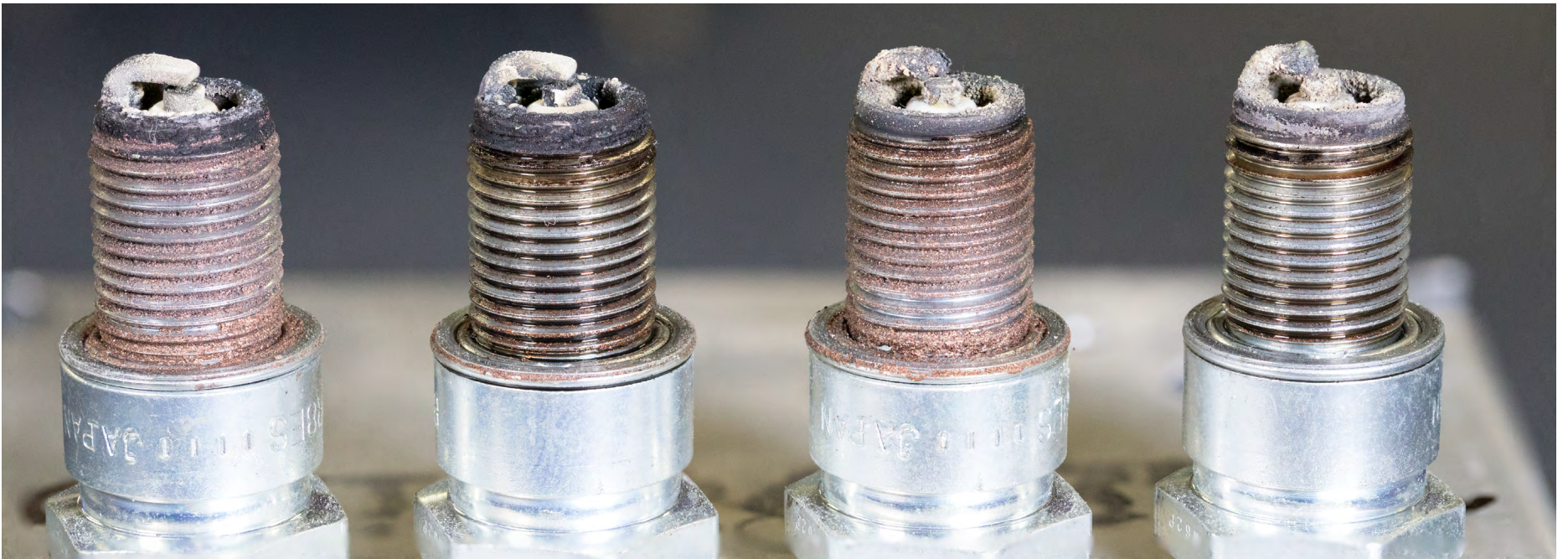


Figure: 10 Spark Plugs In Order PTO on Left Mag on Right

8. Spark plugs (PTO side): Both spark plugs from the PTO cylinder show signs of overheating of the ceramic insulator as indicated by the white color and lack of carbon or any other combustion deposits on the ceramic insulator. However, looking at the rest of the spark plug indicates that the engine had been running rich shown by the indication of black carbon deposits around the perimeter of the spark plug body. This corresponds with an indication of having an overheated cylinder head and not being able to dissipate the heat from both the head and the spark plug.(Figure: 10)
9. Magneto Side Piston: The piston from the magneto cylinder also shows signs of pre-ignition and detonation. Melted metal deposits (from the spark plug electrodes) on top of the piston in the center of the cylinder is an indication of pre-ignition (Figure: 11). Having detonation only would be indicated by the end gas explosions occurring at the perimeter of the piston rather than the center. The most likely source of pre-ignition would be either carbon deposits or spark plug electrodes. On the Rotax 582, ignition from car-



Figure: 11 Metal Deposits



Figure: 12 Magneto Side Piston (Intake Side)

bon deposits most often occurs at the hottest spot on the piston which would be the exhaust side. Based on the shock-wave disruption of the carbon deposits on the top of the piston, they appear to be fairly well distributed and originating from the center of the piston outward. In addition, the burning away of the cylinder head in the area of the upper ring (Dykes ring) (Figure: 12) at the pin and ring end gap is consistent



Figure: 13 Magneto Side Piston (Bottom)



Figure: 14 Magneto Side Piston (Exhaust Side)

with pre-ignition/detonation high-pressure/temperature gases escaping between the ring end gap and burning away the aluminum portion of the piston. It appears as though this area was most likely subject to secondary end gas detonation. This can be identified by the area of clean metal exposed as a result of the localized shock-wave pattern that removed the combustion deposits from this area. As this localized area of extremely high temperature/pressure exits between the ring end gap the velocity and temperature act much like a cutting torch. This melts away the aluminum and the embedding of the aluminum into the cylinder wall begins the cascading effect which results in seizure of the piston. If we compare the discoloration around the perimeter of the PTO side piston with the discoloration around the perimeter of the magneto (failed side) piston, you can see that the discoloration has been worn away by the tight piston to cylinder wall clearances. Both pistons, most likely, looked identical just prior to the engine failure. If we look at the bottom side of the piston, (Figure: 13) we can see the signs of overheating. The discoloration in the aluminum is a sign that the piston has been running at excessive temperatures. The indication of discoloration on the wrist pin is also another indication that the piston has been exposed to excessive temperatures for longer than just the period of time from the last takeoff power application to engine failure. This supports the hypothesis that the engine may have been losing coolant prior to the landing at the Willows airport. In addition, the carbon buildup on the bottom of the piston is also an indication of prolonged operation at above normal temperatures. On a normally operating engine no discoloration or carbon deposits will be evident.



Figure: 15 PTO Side Piston (Bottom)

10. PTO side Piston: (Figure: 15) The PTO side piston also shows signs that the cylinder/piston had been overheating for some period of time. Both the discoloration and the presence of burnt on carbon deposits are evidentiary of this phenomenon. Both rings are floating and free from sticking. This would indicate that the overheating was a fairly recent event. Engines that run at a higher than normal temperature have a tendency to build these carbon deposits also within the ring groove causing the rings to “stick”. At the Dykes ring (top ring) end gap location, there is evidence of the very first signs of melting of the piston. (Figure: 16) On the intake side of the piston there are two vertical striations showing not a visible seizure, but an area of extremely high pressure very similar to what we would refer to as “sympathetic seizure marks” that we would see on the exhaust side of an engine suffering from lubrication injection pump failure, or even as a result of conditions similar to that related to a cold seizure. These are indications that the piston is overheating and has expanded to reduce the cylinder to piston wall clearance to below tolerances. This pressure was sufficient enough to burnish away the machining marks which are normally visible around the perimeter of the entire piston. On the opposite side of the piston there are also two points of high-pressure opposing the pressure points on the intake side of the piston. These will invariably be the first points of failure on the piston and cylinder wall if the engine continued to run in this configuration. The discoloration that encompasses the circumference of the top portion of the piston has been worn away in the high pressure area of the striations. This indicates that the discoloration and overheating occurred prior to the actual failure of the engine. The machining marks around the perimeter of the piston, which we mentioned previously, are one of the most useful tools in determining the quality of the engine overhaul and the subsequent operating conditions. Both of the pistons show extremely low wear. And indicates that the engine was operating correctly up until the subsequent incident.



Figure: 16 PTO Side Piston (Intake Side)



Figure: 17 PTO Side Piston (Exhaust Side)



Figure: 18 PTO Side Piston (Exhaust Side)

11. PTO side cylinder: (Figure: 18) Like the pistons, the crosshatch in the cylinder walls and its condition are one of the prime indicators of proper overhaul and subsequent operating conditions. The quality of the crosshatch within both cylinders is in excellent condition. The quality of the crosshatch would indicate that these are either factory new cylinders, replaced at overhaul, or perhaps a newer engine with the original cylinders. This condition is only achievable through proper crosshatching subsequent proper break-in. This will allow the optimal "Abbotts Firestone Curve" in layman's terms (flat spot to groove ratio). Only properly crosshatch cylinders, which are properly broken in, will typically look in this good of condition at ~300 hours. The cylinder crosshatch in conjunction with the relatively nonexistent wear on the piston skirts as evidenced by the condition of the machined surfaces are the basis for this conclusion. In our experience, we often see cylinders in this condition operate for an additional 300 to 400 hours.

12. Magneto side cylinder: The condition of the magneto side cylinder looks to be similar to that of the PTO side cylinder prior to the engine failure. After the engine failure, transfer of metal corresponding to the seizure locations on the associated piston are consistent with a cylinder in distress as a result of pre-ignition/detonation and subsequent seizure. (Figure: 19)(Figure: 20)



Figure: 19 PTO Side Piston (Exhaust Side)



Figure: 20 PTO Side Piston (Exhaust Side)

13. Mag side Carburetor: Tear-down inspection observations. [{Main jet, 165} --- {Idle jet, 45} --- {Needle Jet, 2.72} --- {Jet needle, 11G2} --- {Clip position, 4} --- {Air Screw, 1.75}] (Figure: 21) based on the tear-down observations we found several anomalies. (1) The clip position was in groove # 4 instead of groove # 3 as recommended, moving the clip down, or if you want to think of it as moving the needle up, causes an increase in the amount of fuel and enriches the mixture. (2) The idle air screw was set at 1.75 turns instead of 1 turn out from the seated position. (3) The o-ring was missing from the idle jet. (4) The idle jet was a 45 instead of a 55. Although we can provide a fairly lengthy treatise on the probable reasoning behind these anomalies, in this particular fail scenario, we do not feel that this would have any significant implication on the basis for the engine failure, and as such will leave this discussion for some other venue. Based on observation of the spark plugs, pistons, and cylinder head, we see evidence that both carburetors were running rich in the midrange of operation. This can be seen in the carbon deposits on the aforementioned components. Tear-down inspection of both carburetors showed signs that the needle jet, and jet needle (Figure: 21) have significant wear. In addition the cir-clip (Figure: 23) that holds the needle in position inside of the carburetor slide also shows signs of significant wear allowing the needle to rotate inside of the needle jet causing wear of both the needle and the jet. The clip should hold the jet needle securely and not allow the needle to rotate. With vibration the contact surface between the clip and the needle may wear. However, the clip is spring loaded to ensure that even during wear friction is provided to prevent the needle from rotating. Over time, the wear may exceed the limit of the clips ability to provide tension and this can be seen in (Figure: 23) where the two contact surfaces of the clip are now in contact with each other preventing tension on the needle. In this case, the clip can be spun without

RECOMMENDED JETTING FOR BING CARBURETORS														
The following is the factory recommended jetting for Bing Carburetors at sea level and 70F degrees. Apply the Bing Main Jet Correction Chart shown on page 12 of this manual to compensate for temperature and altitude at your location. Jetting for engines equipped with intake silencers are also listed.														
Rotax Engines w/o Intake Silencer								Rotax Engines with Intake Silencer						
Engine Type	BING CARB	Main	Idle	Needle	Jet	Clip	Air	Engine Type	BING CARB	Main	Idle	Needle	Jet	Clip
	NUMBER	Jet	Jet	Jet	Needle	From	Screw		NUMBER	Jet	Jet	Jet	Needle	From
						Top								Top
Rotax 277		148	45	2.72	8L2	2	1	Rotax 277		140	45	2.72	8L2	2
Rotax 377		165	45	2.70	8O2	2	0.5	Rotax 377		155	45	2.70	8O2	2
Rotax 377DC		135	50	2.62	8H1	2	0.5	Rotax 377DC						
Rotax 447 SC	54/36/2002	165	45	2.70	15K2	2	0.5	Rotax 447 SC	54/36/2001	155	45	2.70	15K2	2
Rotax 447DC		135	50	2.70	6G1	3	1	Rotax 447DC		128	50	2.68	15K2	2
Rotax 503SC*		180	45	2.74	8G2	3	0.5	Rotax 503SC*		158	45	2.74	6H2	3
*Up to Serial #3785371								*Up to Serial #3785371						
Rotax 503SC**		185	45	2.72	15K2	3	0.5	Rotax 503SC**		165	45	2.70	15K2	3
** After Serial # 3785372								** After Serial # 3785372						
						2								
Rotax 503DC 34kW	54/36/2003	185	45	2.72	15K2	3	0.5	Rotax 503 DC 34kW	54/36/2004	165	45	2.70	15K2	3
Rotax 503DC 37kW	54/36/2006	158	45	2.70	11K2	2	0.5	Rotax 503DC 37kW	54/36/2005	148	45	2.68	11K2	2
Rotax 532SC		195	55	2.74	15K2	3	1	Rotax 532SC		170	55	2.74	15K2	3
Rotax 532DC		165	55	2.72	11G2	3	1	Rotax 532DC		145	55	2.68	15K2	2
Rotax 582DC 40kW	54/36/2102	160	55	2.72	11G2	3	1	Rotax 582DC 40kW	54/36/2101	145	55	2.68	15K2	3
Rotax 582DC 48kW	54/36/2103	165	55	2.72	11G2	3	1	Rotax 582DC 48kW	54/36/2101	145	55	2.68	15K2	2
Rotax 618DC-pto		160	50	2.68	9M1OJ	2	1.5	Rotax 618DC-pto		135	50	2.68	9M1OJ	2
Rotax 618DC-mag		170	50	2.68	9M1OJ	2	1.5	Rotax 618DC-mag		145	50	2.68	9M1OJ	2
								Rotax 618 Standard		135	55	2.7	15E5U	3

Figure: 21 Rotax Carb Settings Chart



Figure: 22 Jet Needle (Mag Side Carb)

resistance around the perimeter of the needle. This, in turn, accelerates the wear on the clip, needle jet, and jet needle. In addition, the o-ring on top of the circlip was missing from the mag side carburetors. The purpose for this o-ring is to help stabilize the needle and reduce the amount of vibration and subsequent wear on the needle jet and jet needle. Running rich in the midrange has correlative importance in this case inasmuch as excessive carbon buildup can be a source of pre-ignition in many scenarios. But more importantly, it may contribute to the reason for the engine failure occurring at the particular point in the mission profile. In the cruise, approach, and landing profile the reduced manifold pressure accompanied by the excessively rich mixture may have prevented the engine from reaching temperatures conducive to pre-ignition. The needle jet/jet needle provide the mixture setting that correlates with the 1/4 - 3/4 throttle setting. Once above the 3/4 throttle setting the primary controller of the mixture is the main jet. At full throttle, as in the case of this engine failure, the needle jet and jet needle have no effect upon the mixture. Upon inspection, the main jet is the proper jet and appears to be in proper operating condition, and free from contamination or corrosion. The float level (Figure: 24) is also set up correctly. The wear on the carburetor slide is indicative of a carburetor that has been in service longer than the last ~300 hours of operation since the estimated of the last engine overhaul. In addition, the overall condition of the carburetor looks as though the engine overhaul at ~300 hours ago may have been the last time that the carburetors were also overhauled. This is supported by the amount of wear on the needle jet and jet needle, condition of O-rings (Figure: 25), and age and deterioration of gaskets.



Figure: 23 Jet Needle Circlip (Mag Side Carb)

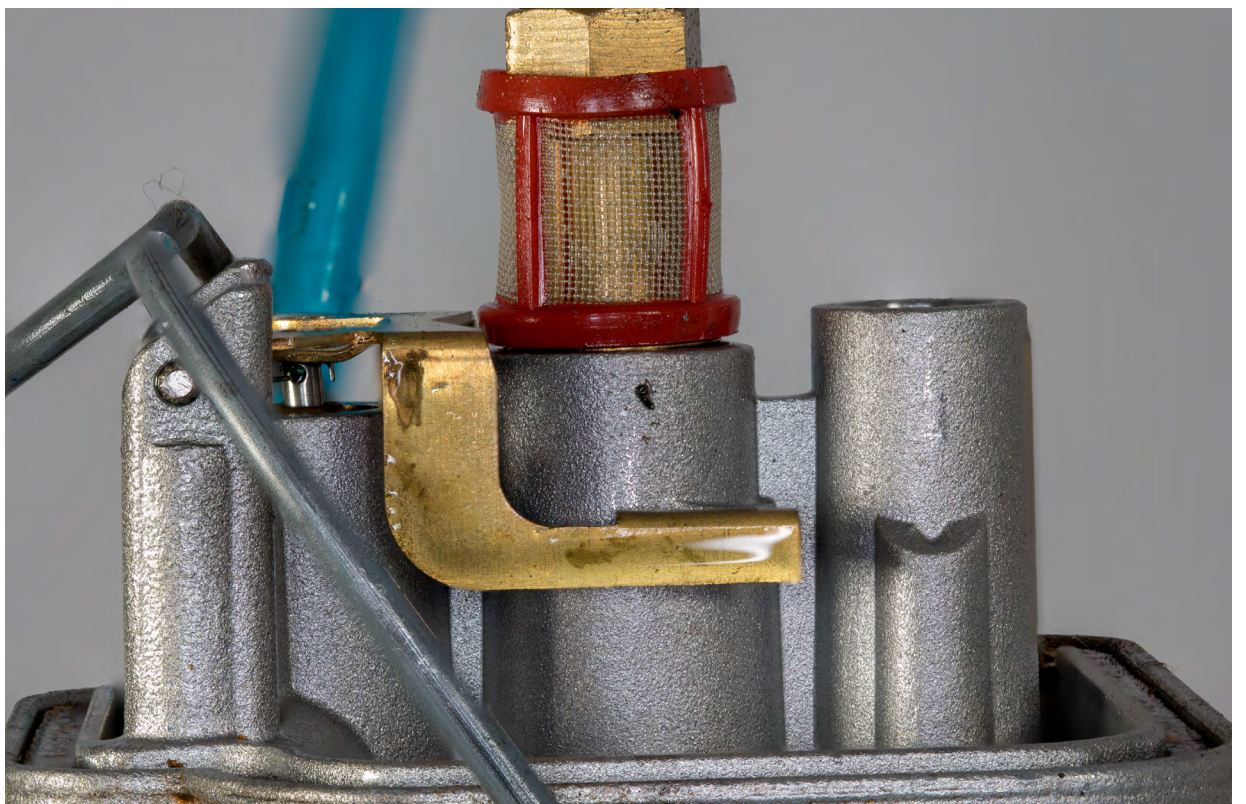


Figure: 24 Float Level (Mag Side Carb)

14. Carburetor Top Cap: having an air leak around the o-ring for carburetor top cap does have the potential to allow air to leak into the top of the carburetor and transition through the bleed holes in the slide causing a slightly leaner mixture. This can also be true if the rubber boots on the throttle cables have deteriorated as well. Although, we have ample evidence that the majority of aircraft operating these type of carburetors have deteriorated cable boots, the number of direct failures as a result of this condition remains unknown. There is a sound theoretical basis for concern and the result is invariably a leaner condition within the



Figure: 25 Carb Cap O-Ring (Mag Side Carb)

engine throughout the entire range of operation. And although considered unacceptable, there are enough airplanes operating in this configuration to assume that it leans the mixture only slightly in the entire scheme of things. This being said, in a critical situation this may contribute to certain failures and the possibility of it contributing to this failure must be taken into account. In the case of the GT-500, both carburetors were suffering from degradation of the o-ring around the perimeter of the cap.

15. PTO Side Carburetor: Tear-down inspection observations. [{Main jet, 165} --- {Idle jet, 55} --- {Needle Jet, 2.72} --- {Jet needle, 11K2} --- {Clip position, 4} --- {Air Screw, .5}] (Figure: 21) several anomalies were found on this carburetors well. (1) The clip position was in groove # 4 instead of groove # 3 as recommended. This would cause the mixture to be enriched in the midrange. (2) the idle air screw was set at .5 turns instead of 1 turn out from the seated position. (3) The o-ring was missing from the idle jet. (4) The float level was improperly adjusted. (Figure: 26) In this case, the float level was set higher than normal. This would increase the mixture throughout the entire range of power settings. This would also support the hypotheses that the PTO cylinder was running richer and as a result cooler, this causing the failure of this cylinder to lag behind slightly in its failure in comparison to the magneto side cylinder. (5) The jet needle (Figure: 27) was an 11K2 instead of 11G2. The higher code letters will produce a richer mixture below at the half throttle setting and below. One of the primary indicators of excessive wear on the needle is a visual inspection of the area with the needle part number stamped into the body of the needle. In this case, you can see an excessive amount of wear to the point that the numeral 2 is completely worn away. This is the area where the needle makes contact with the carburetor slide. And although this clip is tight against the needle groove and has the o-ring intact, based on the amount of wear an inspection of the clip reveals

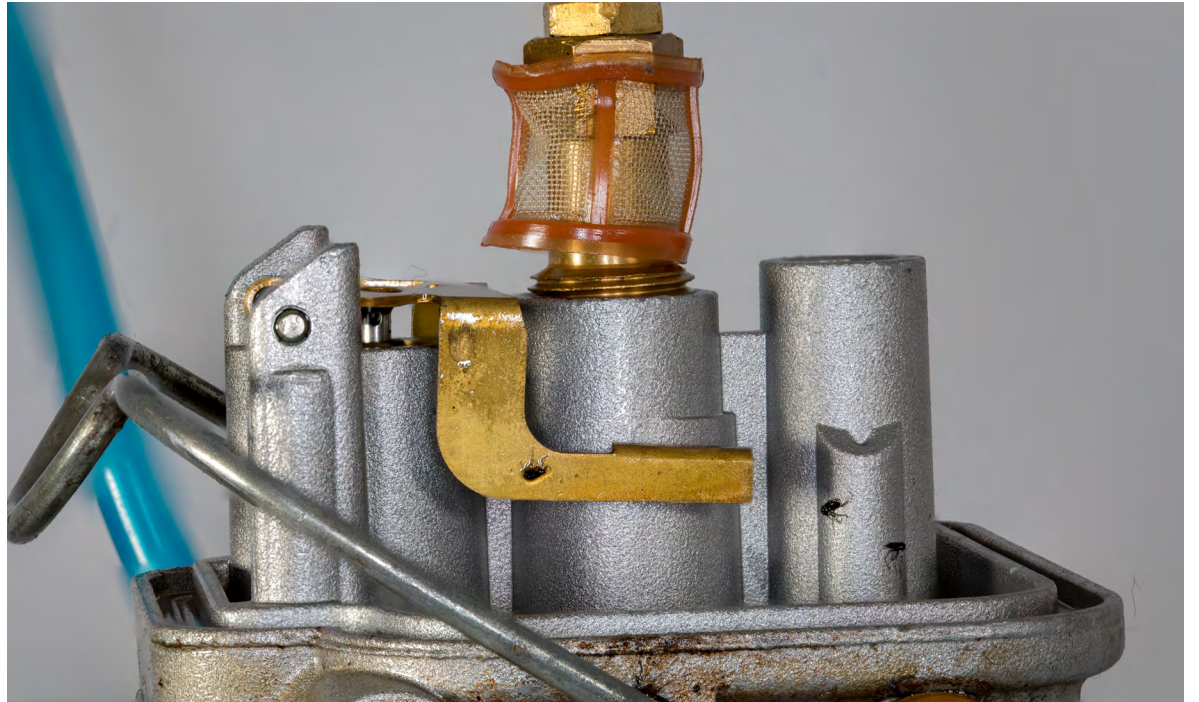


Figure: 26 Float Level (PTO Side Carb)

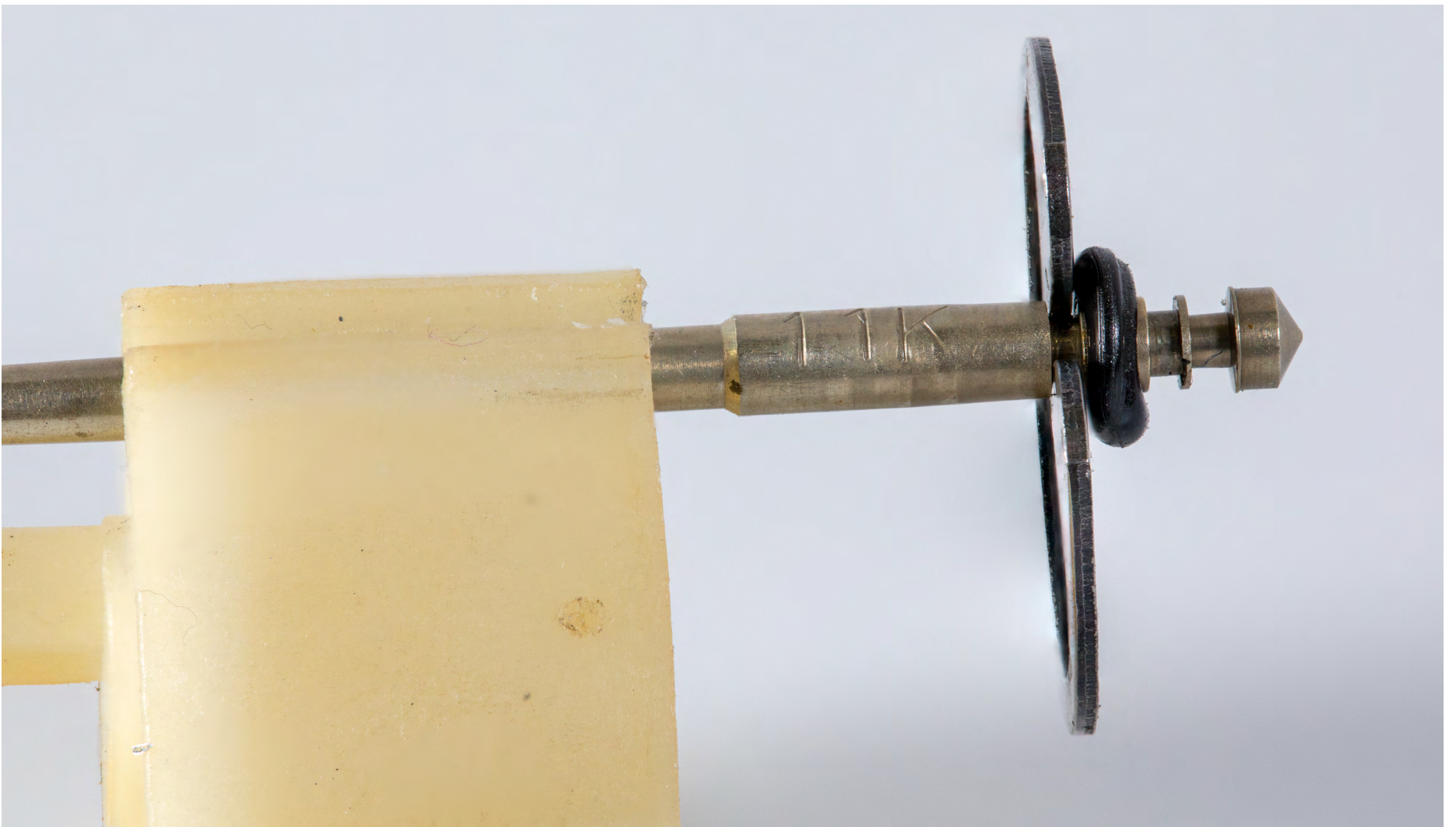


Figure: 27 11K2 Jet Needle (PTO Side Carb)

that the gap between the clip faces has reached its limit. Experience has shown that this should have been removed from service well over 100 hours ago.

16. Carburetor wear: carburetor wear is not only found on the needle jet / jet needle, and E clip, but on all moving parts within the carburetor including the piston/slide. (Figure: 28) All of this wear is symptomatic of a greater problem. The root cause of the wear within both carburetors can be attributed to many different factors. (1) Idling at two low of RPM or improper idle mixture settings. In this case, we know that both carburetors are fairly screwed up when it comes to the idle circuit. (2) High moment of inertia propellers. This aircraft



Figure: 28 Carburetor Slide (PTO Side Carb)

uses a Warp drive, three bladed, solid carbon fiber, ground adjustable propeller which has a relatively high moment of inertia. (3) Propeller tracking (not checked) (4) propeller balance (also not checked) (5) Carburetor synchronization, which was found to be mis-adjusted. Depending on the severity of any one of these different anomalies will determine the amount of wear that occurs not only on the carburetor, but the rest of the engine and airframe as well. Although, all of this wear is of importance in the bigger picture, all of the components suffering from wear were not a factor in the primary cause of engine stoppage. In the full throttle configuration, only the main jet is controlling the mixture setting. And the main jets were found to being good condition and the proper part number with no evidence of modification.

17. Carburetor synchronization: Although there were the very first signs of pre-ignition or detonation within the PTO side cylinder, they were minuscule in relationship to the pre-ignition and detonation that occurred within the magneto side. Because the root cause of the failure was related to the lack of coolant within the radiator system, we typically look for signs that support this hypotheses within both cylinders simultaneously. The correlative signs, in this case, were supported by the white color of the spark plug insulators as well as the shock-wave burn pattern on the top of the piston and the first signs of deterioration of the piston at the ring gap. And although the PTO side cylinder did not suffer a failure, we speculate that a similar scenario could have occurred on the PTO side cylinder and piston. Typically, in failures such as these, the short time interval from full power application to engine failure (~ 15 sec.) results in failure of the most critical component first. The carburetor synchronization was measured and found to be .040 inches differential with the magneto side carburetor slide open more than the PTO side carburetor slide. Under normal circumstances, this differential would not be critical. However, with the magneto side cylinder carrying a slightly higher manifold pressure, this would increase the pressures and temperatures within that cylinder and most likely be the cause of the magneto side cylinder failing first. Typically, when one cylinder starts to suffer pre-ignition/detonation, the power output from that cylinder dissipates. This, in turn, transfers the load onto the other cylinder which would in turn increases the load on that cylinder. This may have been the point at which the PTO side cylinder began some initial detonation, however this component of the analysis is speculation.
18. Crankshaft and Crankcase: (Figure: 29) Inspection of the crankshaft, main bearings, and connecting rod bearings showed no anomalies. In fact, the bottom end of the engine appeared to be in excellent condition.
19. Connecting Rod: (Figure: 30) Inspection of the connecting Rod revealed no anomalies. However, it is important to look at the wrist pin and needle bearing race. Typically, when an engine has been running hot

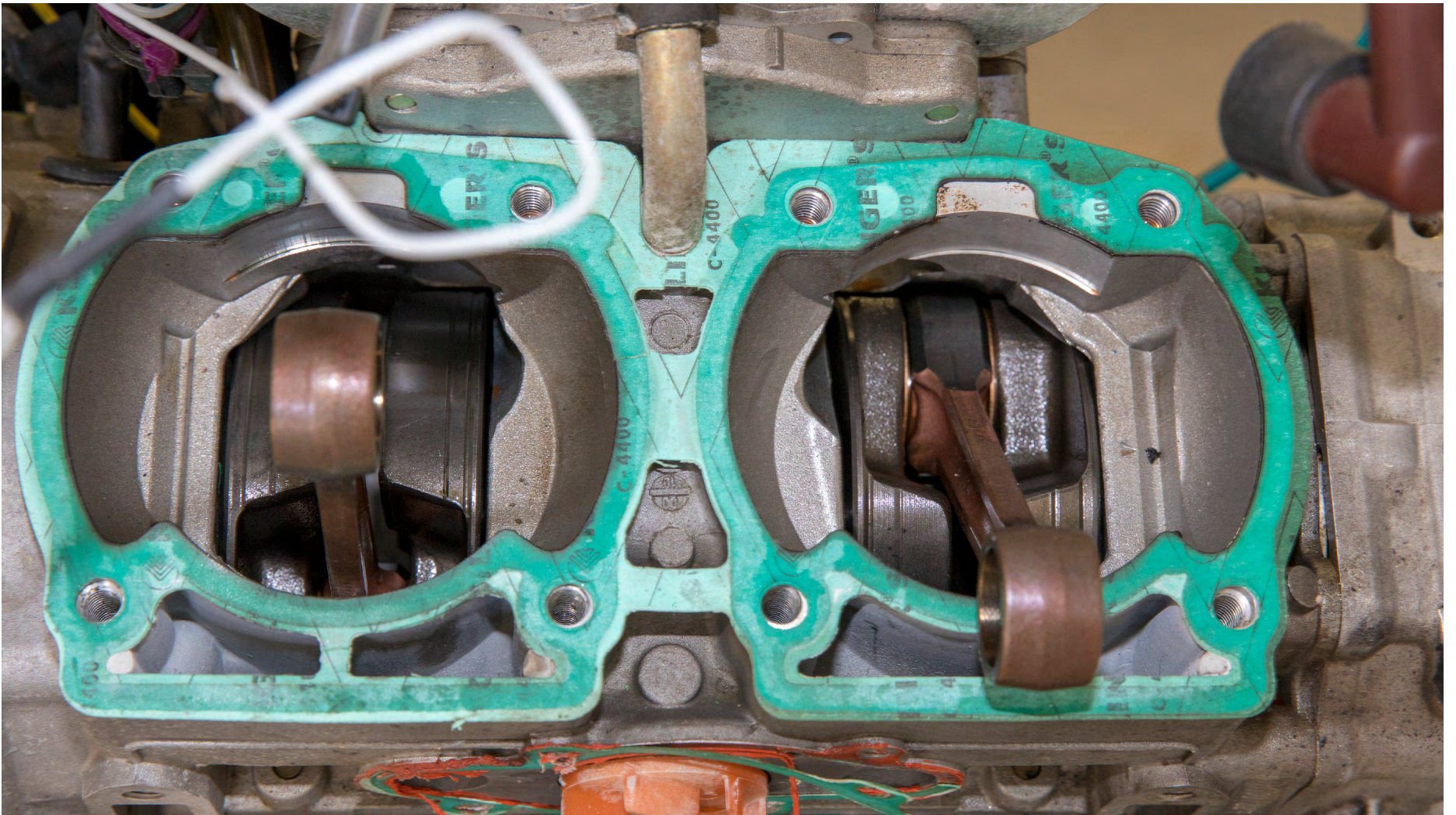


Figure: 29 Crank Case and Crankshaft

for quite some time, we will see discoloration of this area of the connecting rod. In this case, there is no evidence of excessive heating over a long period of time. This may provide further evidence that the heating that we see on the pistons was a fairly recent phenomenon.



Figure: 30 Connecting Rod

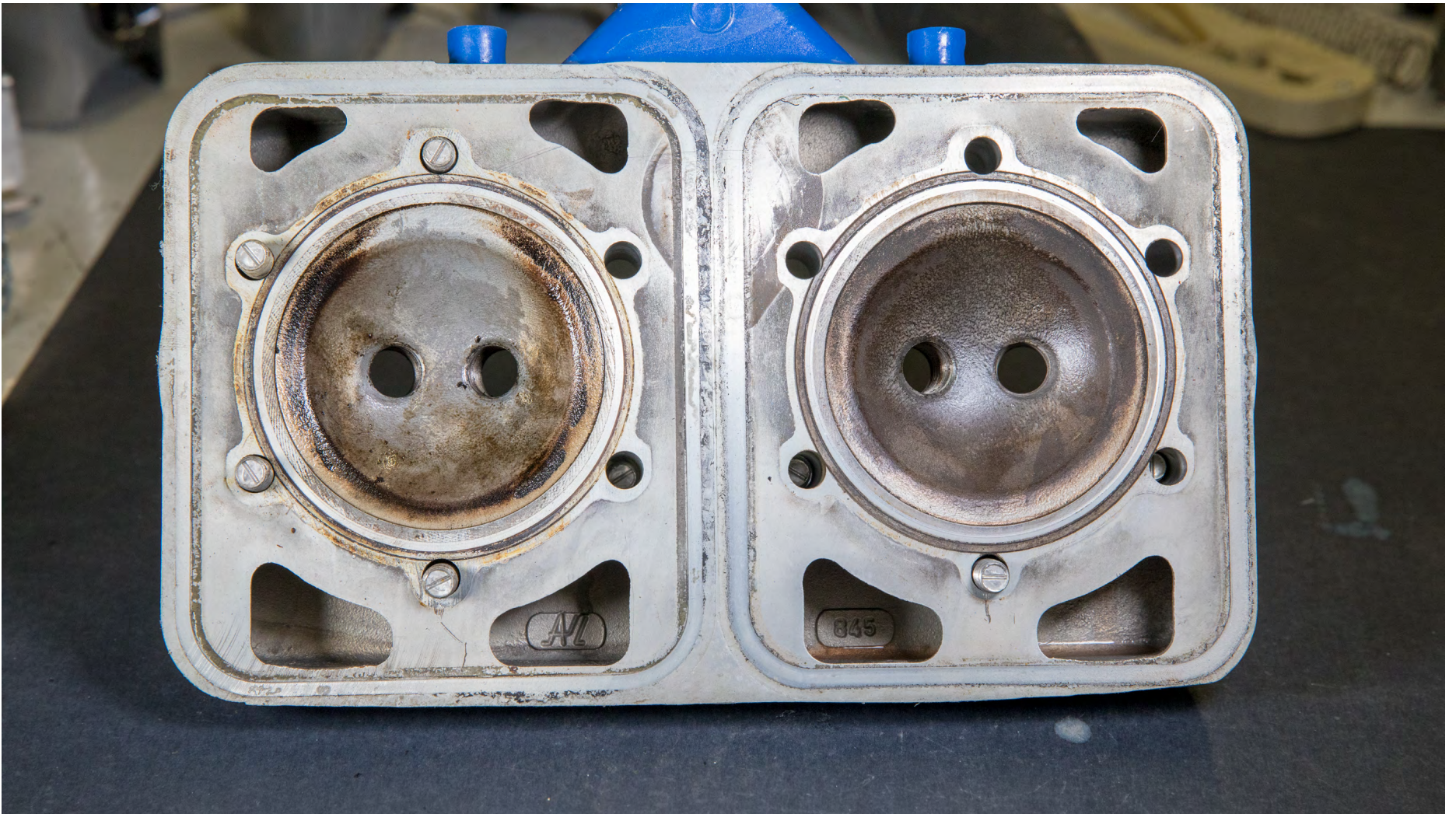


Figure: 31 Cylinder Head

20. Cylinder Head: (Figure: 31) shows indications that are consistent with the findings within the cylinders and on the pistons. In this picture, the PTO cylinder is on the left and the magneto cylinder is on the right. The shock-wave disruptions of the carbon buildup show a typical end gas detonation condition within the “squish zone” (outer perimeter). Due to the mass of aluminum within the head, even with the lack of water within the cooling system, it is typical for the pistons to show the first sign of degradation prior to damage to the cylinder heads.
21. Engine run-up: From engine start to application at the beginning of the takeoff run the total time frame was approximately 04 minutes and 11 seconds. This is a relatively short and inadequate amount of time to warm up the engine and prevent a “cold seizure”. In addition, the actual run-up itself occurred at a relatively low power setting, approximately 3000 RPM and lasted only about thirteen seconds. Under normal conditions, this amount of “heat soaking” of the engine would be marginally acceptable to prevent a cold seizure. The engine had been sitting for approximately 45 minutes since the last time that it was shut down. This time frame would have rendered the engine cold enough to warrant a complete warm-up prior to flight. However, upon inspection, the telltale cold seizure indications were not definitive. A cold seizure can be identified by the classic four quadrant seizure and scuffing of the piston at the edges adjacent to the wrist pin cutaways. A cold seizure is simply the aluminum piston growing in size as a result of heating at a faster rate than the steel sleeve within the cylinder. This causing a reduction in cylinder to piston wall clearance sufficient to eliminate the clearances necessary to retain a barrier of lubricating oil between the piston and cylinder. This cylinder to piston contact results in transfer of aluminum from the piston into the surface crosshatch of the steel cylinder, in turn causing additional heat, cascading into a seizure and sudden engine stoppage.
22. Engine indications: Although the pilot did not indicate that he noticed any anomalies on the engine instruments before takeoff, there is the possibility that the indications were erroneous due to the lack of coolant within the cylinder head. If the water had dropped or had boiled within the cylinder head, it would be very likely that water temperature would be indicating incorrectly even before takeoff. It is likely that there was a drop in the exhaust gas temperature just after pre-ignition and detonation. However, the time-frame from first indication to engine seizure was only three seconds. Typically, even quick throttle response to pre-ignition in the scenarios is inadequate to change the outcome.

Summary

It is likely that the aircraft had lost a significant amount of coolant during the previous legs of the cross-country flight. The most likely source of coolant loss was the hose at the water pump housing nipples. This loss of coolant coupled with the short run up time the aircraft was able to get airborne before the cylinder heads had reached a critical temperature. Within ~ 15 seconds after full throttle application the first signs of pre-ignition and detonation can be heard on the video. ~ 3 seconds later the first signs of engine seizure can be heard. And the engine has come to a complete stop within the following ~4 seconds after that.

Conclusions:

1. Water pump housing construction: The poor quality of the water pump housing made it difficult if not impossible to properly seal the hose to nipple attachment.
2. Maintenance: The coolant leak appears to have been evident and present for quite some time. Identification of the leak as a significant and potential hazard could have prevented this accident.
3. Radiator Recovery Bottle: Proper installation of the radiator recovery and overflow bottle would likely have refilled the radiator. Based on the observed amount of leak, proper installation of the recovery bottle would likely have prevented the engine failure. In addition, the diminishing quantity of coolant in the recovery bottle would have reinforced and identified the significance of the existing leak.
4. Preflight inspection: Conducting a more thorough preflight with the inclusion of coolant level check could have prevented this particular failure.
5. As with so many accidents, there is a whole chain of events that has to happen in order for the final outcome to be realized. And although we have narrowed down the chain of events to four primary areas, this leaves four corresponding opportunities to have intervened and prevented the failure of the engine.

Post Script:

Although we have summarized the reason for the engine failure, we are certain that you have identified the shortcomings on the piloting side of the accident. We feel compelled to share our personal opinion regarding the element of human error. The outcome, after the engine stoppage, should have been much different. For years we have been training pilots in these type of light aircraft. We refer to them as the high drag, low mass aircraft. And because we have identified this as one of the primary shortcomings of general aviation pilots, moving down to light sport and ultralight aircraft, we discuss this very scenario in both of our books "A Professional Approach to Ultralights" and "Sport Pilot - Airplane". This accident, and many others of this type, turns out to be nothing more than a simple lack of specialty training for both the student and the instructor. Not something that can be learned by reading. It needs to be practiced to be successful. We are currently working on a companion video with a step-by-step explanations and associated animations to be used for training purposes.