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BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL PANEL
Christine Kohl, Chairman

Enclosed are references mistakenly omitted from AWPP (Romano) Appeal re Contentions Denied by The Board in 2nd PID served on Board Oct. 10, 1984 by Express Mail.

Air & Water Pollution Patrol
Frank R. Romano, Chairman
61 Forest Ave.
Ambler, Pa. 19002

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PDR ADOCK 05000352
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DS02

SAFETY CORNER

BY THOMAS A. HORNE
AOPA 566732

CARBURETOR ICE: STILL A THREAT

Thanks to a vast amount of publicity and continued emphasis by flight instructors, nearly all pilots are aware of the dangers of carburetor ice. Awareness doesn't seem to be enough, however, because accident statistics continue to reflect a misunderstanding of the operation of the carburetor heat equipment used to combat this serious problem.

Carburetor ice forms when outside air of a sufficient moisture content enters the Venturi section of a normally aspirated engine's carburetor. The resultant cooling due to vaporization and the accelerated, lower pressure air at the Venturi tube (a narrowed passage in the throat of the carburetor) promotes the formation of ice on the internal parts of the carburetor. Unless something is done, the buildup of ice will continue to the point that the engine's air supply is cut off, and the pilot is faced with a forced landing.

Float-type carburetors have the worst icing design because fuel is injected ahead of the Venturi, and ice forming downstream of the area of vaporization tends to adhere at the worst possible places for ice to accumulate—the Venturi itself and the throttle's butterfly valve.

Pressure carburetors, though, inject fuel downstream of the Venturi and thus away from this refrigerated area, lessening the likelihood of icing in this type of system.

Fuel-injected engines are free from the problems of carburetor icing since they use a design that injects fuel directly into the cylinder head.

The range of ambient conditions conducive to the formation of carburetor ice is quite wide. Ice can form whenever outside air temperatures range from 10°F to 100°F, when dew points range from 10°F to 82°F and whenever relative humidities are greater than 20 percent.

When the right combination of variables exists, the pronounced temperature drop that occurs in the carburetor (this can be as much as 70°F) will cause ice to form. Consult the accompanying icing probability chart to see just how many combinations can exist that could give rise to carburetor ice.

A pilot should suspect carburetor ice whenever he experiences a sudden engine roughness or vibration, an otherwise unexplainable drop in rpm's in a fixed-pitch propeller aircraft or a drop in manifold pressure in a constant-speed propeller aircraft. These are the traditionally taught warning indications. There are some other ways of detecting the onset of carburetor ice.

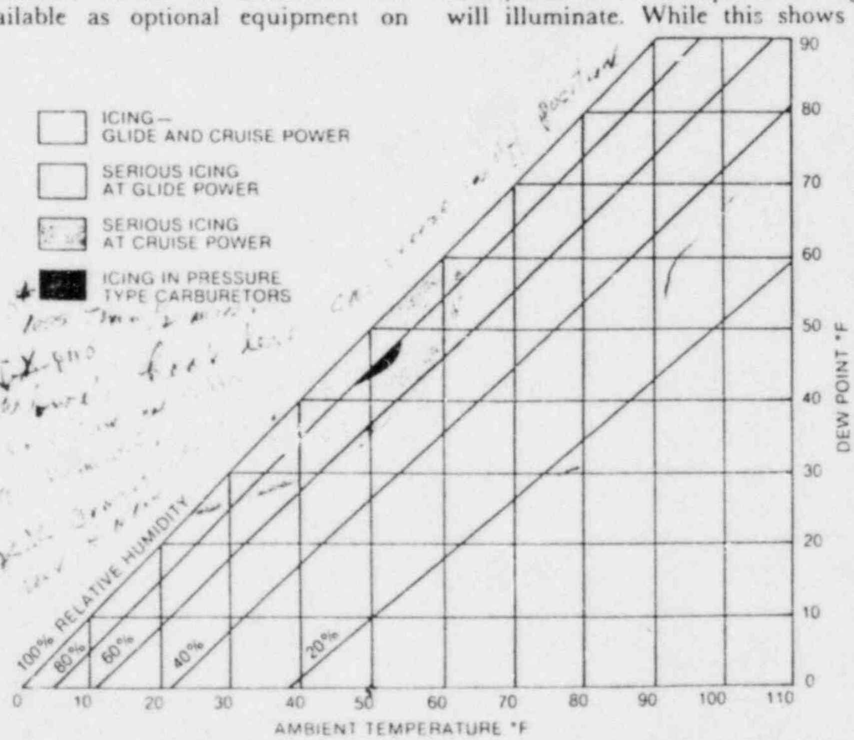
If the airplane is flying at a constant altitude, then any drop in airspeed also would signal a loss of power, and this hint of trouble may precede any other engine or instrument indications.

The exhaust gas temperature gauge also may be useful in indicating ice formation in the carburetor. A drop in EGT from a mixture becoming progressively richer would mean that the engine's air supply is being lessened, possibly from the effects of ice formation. This is assuming a constant power setting is being maintained.

A way to check for icing is to note the manifold pressure or rpm's, then apply full heat for five seconds or so. If a return to the cold position gives you higher rpm's or manifold pressure than indicated before, you have encountered ice, and should continue to intermittently use carburetor heat (or follow the procedures in your aircraft and engine operating manuals).

Special instruments to detect icing conditions within the carburetor are available as optional equipment on most airplanes. The Richter carburetor-air-temperature gauge is one of the most popular. In this arrangement, a temperature probe is installed just below the butterfly valve, and a gauge in the cockpit gives an indication of icing temperatures (yellow arc) and safe temperatures (green arc). While this does a fine job of showing the temperature conditions within the carburetor, the pilot still doesn't know the moisture content of the incoming air. If the pilot uses partial carburetor heat to maintain temperatures in the green, he would be doing more harm than good, since in cold temperatures (below 32°F) application of partial heat would melt ice crystals that ordinarily would harmlessly pass through the engine, actually causing ice to form while the instrument still indicates a safe temperature. To ensure that this doesn't happen, keep the carburetor temperature at 32°C, or 90°F (needle pegged to the right) when using carb heat with this instrument.

ARP's optical probe uses a photo cell in the neck of the carburetor to detect carburetor ice. The presence of ice will interrupt the light beam it emanates, and in the cockpit a red light will illuminate. While this shows us



Carburetor Icing Probability Chart. Note the narrow range of conditions that produces icing in pressure carburetors. Float-type carburetors (by far the more common) have a design that can produce ice in all the conditions represented by the shaded areas. Light icing conditions can become severe after 15 minutes of continuous operation.

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what we really want to know—that ice is in fact present—the warning could come too late because it has been shown that ice can form and shut down an engine in less than a half-minute under the right circumstances.

The Shivers electrical probe consists of wiring that wraps around the butterfly valve itself and gives a cockpit indication when ice grounds it out.

Regardless of how you come by the suspicion that carburetor ice may be forming, the proper procedure is to apply full carburetor heat *immediately*. This is the only way to be certain of melting the ice, and you will have the assurance that the temperature will be high enough to prevent the melting and refreezing of subfreezing air inside the carburetor. It's important to apply heat as soon as possible because ice can form rapidly enough to freeze the carburetor heat valve in the off position, thus assuring an engine failure. What's more, since carburetor heat comes from a heat exchanger mounted on the exhaust system, it is dependent on the continued operation of the engine. If the engine is allowed to quit, no heat will be available to help attempt a restart.

Once heat has been applied, expect considerable engine roughness. This is because the engine is ingesting the melted ice. Accompanying this will be a drop in rpm's or manifold pressure, airspeed and perhaps altitude. All of these things may frighten you into returning the carburetor heat control to the off position, but you should resist that temptation. This almost certainly would cause an engine stoppage as the partially melted ice refroze.

After the roughness abates, you will notice a rise in rpms or manifold pressure. Then you can return the carburetor heat control to the off position. There should be an additional rise in power, indicating that the ice has been cleared. If this doesn't happen, put the heat back on and wait again.

Since the application of heat causes a lighter, less dense flow of air into the engine, you can lean the mixture to obtain higher temperatures from the engine, which in turn raises the temperature of the carburetor heat, giving you more melting power. Increasing the power setting also will provide more heat. When the initial bout with carburetor ice is over, it is a wise idea to increase power and lean the mixture in conjunction with carburetor heat in order to forestall any further chances of ice formation. Do this with caution, because if you overlean you may stop the engine. Then, with no heat available, a restart would be unlikely.

As a last resort, a badly iced engine can sometimes be relieved by inducing

Is standard instrumentation good?

Page 19, Page 20

Attachment B

DOT/FAA/CT-82/44

Light Aircraft Piston Engine Carburetor Ice Detector/Warning Device Sensitivity/Effectiveness

William Cavage
James Newcomb
Keith Biehl

June 1982

Final Report

This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

US Department of Transportation
Federal Aviation Administration
Technical Center
Atlantic City Airport, N.J. 08405

INTRODUCTION

PURPOSE.

The Federal Aviation Administration (FAA) Technical Center's propulsion effort is centered on the safety and reliability aspects of propulsion systems for both turbine and piston engines. The detailed planning and objectives of the FAA Technical Center's propulsion program is documented in an Engineering and Development Program Plan — Propulsion Safety Report, FAA-ED-18-5A, April, 1981. Aircraft piston engine safety and reliability is highlighted as an area of concern, particularly induction system problems associated with carburetor icing, induction system moisture ingestion, and carburetor antideicing. The detailed objective of this plan is to establish test cell engine operation during carburetor ice producing conditions, optically observe real-time carburetor icing operating conditions, and determine sensitivity of existing "off-the-shelf" carburetor ice detection equipment.

BACKGROUND.

Accident/incident data involving conditions conducive to carburetor/induction system icing as a cause/factor is available from the FAA computer system located in Kansas City, Missouri which contains both FAA and National Transportation Safety Board (NTSB) data. A review of this data reveals a substantial number of occurrences where carburetor icing was the "most probable cause" of general aviation engine failure while in flight. The term "most probable cause" is used due to difficulty in substantiating the insidious culprit which generally dissipates prior to examination of engine conditions.

Presently, on the aviation instrument market are items which propose to afford the pilot a warning when conditions conducive to carburetor icing are present. A problem which appeared in several accounts of carburetor icing incidents while using these available instruments was the fact that accuracy and sensitivity may be questionable.

The NTSB, FAA, Military, Foreign Aviation Agencies, and various pilot organizations have files full of technical reports and published articles dealing with carburetor icing accidents/incidents. The topic has been well researched and published, providing icing probability curves (figure 1) for pilot education to preclude a dangerous situation. Various individuals have directed their efforts toward developing cockpit instrumentation capable of warning the pilot of actual ice formation, or at least alerting them to the fact that carburetor conditions are conducive to ice formation (depending on atmospheric properties). Other individuals have pursued carburetor modification which will limit engine power loss during carburetor icing and prevent engine stoppage.

A review of various reports on carburetor icing reveal that pilots may be lured into a false sense of security while using carburetor ice detectors/warning devices. Reports have been published in monthly periodicals by individuals indicating that these off-the-shelf instruments may not have the accuracy and sensitivity required to provide adequate carburetor protection. When one reads the literature on available instruments, they may be led to believe that the FAA Supplemental Type Certification (STC) has certified the instrument as an accurate reliable cure-all to icing problems.

Table 7 referred to on page 12 of AWPP Appr. should be table 2, page 7.

1. Weather conditions - Table 2
2. Phase of flight - Table 3
3. Occurrences by region - Table 4
4. Occurrences by rating - Tables 5 and 6
5. Occurrences by aircraft model - Table 7
6. Occurrences by month of year- Figures 4 and 5
7. Occurrences by pilot hours (private and commercial) - Figures 6 and 7

TABLE 2. WEATHER CONDITIONS DURING CARBURETOR ICING ACCIDENTS/INCIDENTS (1976-1980)

CONDITION	NUMBER
Low Ceiling	7
Fog	14
Freezing Temperature	4
Heavy Freezing Rain	1
Heavy Snow	3
Light Freezing Rain	4
Light Snow	4
Light Rain	12
Weather Not a Factor	259
Thunderstorm	2
Wind	7
Unknown	2
Other	10
Total	329

TABLE 3. PHASE OF FLIGHT DURING CARBURETOR ICING ACCIDENTS/INCIDENTS (1976-1980)

PHASE OF FLIGHT	NUMBER
Approach	59
Climb to Cruise	6
Cruise	159
Descent	6
Taxiing	2
Landing	14
Takeoff	66
Touch and go	2
Simulated Forced Landing	4
Practice Maneuver	1
Unknown	10
Total	329

TABLE 6. PILOT CERTIFICATE/RATING FOR CARBURETOR ICING ACCIDENTS/ INCIDENTS 1976-1980

CERTIFICATION	RATING	1976	1977	1978	1979	1980
STUDENT	No Rating	9	10	13	7	8
PRIVATE	ASEL	25	19	28	29	42
PRIVATE	ASE ASES	0	2	3	1	2
PRIVATE	ASMEL	1	1	1	3	1
PRIVATE	RH ASEL	0	0	0	1	0
PRIVATE	UNKNOWN	0	0	1	0	1
COMMERCIAL	ASEL	9	8	6	5	6
COMMERCIAL	ASEL ASES	1	1	1	2	0
COMMERCIAL	ASMEL	10	10	8	4	5
COMMERCIAL	ASMEL ASES	2	0	0	1	1
COMMERCIAL	RH ASMEL	0	0	3	2	1
COMMERCIAL	RH	0	1	0	0	1
COMMERCIAL	ASMEL ASES	C	0	1	1	0
COMMERCIAL	RH ASEL	0	0	3	1	0
COMMERCIAL	G RH ASMEL	0	0	1	0	0
COMMERCIAL	G ASEL	0	1	0	0	0
COMMERCIAL	G ASEL ASES	0	0	0	0	1
COMMERCIAL	UNKNOWN	[illegible]	0	2	0	0
CERTIFIED FLIGHT INSTRUCTOR (CFI)	ASEL	0	0	1	1	1
CFI	ASMEL	0	0	4	3	1
CFI	ASMEL ASES	0	0	0	2	1
CFI	UNKNOWN	0	0	0	0	2
CFI	G RH ASMEL	0	0	0	1	0
AIRLINE TRANSPORT	ASEL	1	0	0	0	0
AIRLINE TRANSPORT	ASMEL	2	1	2	1	2
AIRLINE TRANSPORT	ASMEL ASMES	2	0	0	0	0
AIRLINE TRANSPORT	ASMEL ASES	0	0	1	0	0
AIRLINE TRANSPORT	RH ASMEL	0	0	1	0	0
AIRLINE TRANSPORT	UNKNOWN	0	0	0	0	2
AIRLINE TRANSPORT	ASMEL	0	0	1	0	0
FLIGHT INSTRUCTOR	ASMEL	0	0	0	0	0
UNKNOWN		0	0	0	0	1

RATING ABBREVIATIONS

ASEL - Aircraft Single Engine Land
ASES - Aircraft Single Engine Sea
AMEL - Aircraft Multi-Engine Land
AMES - Aircraft Multi-Engine Sea
ASMEL - Aircraft Single Multi-Engine Land
ASMES - Aircraft Single Multi-Engine Sea
RH - Rotorcraft
G - Glider

2. At low power settings or prolonged periods of time at reduced power settings adequate heat may not be available to overcome impact of ice accumulation.

3. Application of carburetor heat will momentarily cause an increase in engine roughness which entices the uninitiated pilot to turn off heat. Roughness is caused by water ingestion as ice melts, plus the application of heat causes enrichment of fuel-air mixture.

4. Performance degradation may not be caused by ice formation.

5. Performance degradation does not appear at initiation of ice formation, but rather after an accumulation has developed.

6. When carburetor temperature is well below freezing, there are times when the application of heat will make icing conditions worse, however, pilot doesn't always know when these conditions exist.

OPTIONAL INSTRUMENTATION. In addition to the standard cockpit instrumentation required by FAR's, there are optional instruments available on the market shelf which have been approved by the FAA on a no-hazard basis with the issuance of STCs for installation in type certificated aircraft. Such instruments are approved as optional equipment only and flight operations should not be predicated on their use. STC approval is not extended to other specific engines of the approved models on which other previously approved modifications are incorporated unless it is determined that the interrelationship between changes/modifications will introduce no adverse effect upon the airworthiness of that engine. Appendices C and D are examples of typical STC approvals.

Two off-the-shelf instruments which are commonly installed as carburetor ice detection/warning devices were evaluated within this report. For the purpose of this report these instruments are listed as Test Probe 1 and Test Probe 2.

Test Probe 1. The Test Probe 1 system is completely independent of temperature or pressure changes which do not affect detector operation except to melt away frost/ice accumulation. By means of a transistorized electrical circuit, a warning light mounted on the cockpit instrument panel, is actuated during blockage of light rays by frost/ice accumulation between the radiation source and the probe sensor, both of which are located inside the carburetor.

The panel mounted warning light also incorporates a sensistivity control which may be adjusted on the ground or in flight to regulate light activation. An optional warning horn may be included with system installation.

As discussed in the Test Probe 1 SYSTEM TESTS portion of this report, 18 separate test runs were performed in the static sea level engine test cell using Test Probe 1. Data compiled during test operations, which totaled 30.85 hours of engine operation, lead to the conclusion that the instrument is a useful cockpit item. There are some shortcomings inherent in Test Probe 1 system design/probe location as described in detailed in the ENGINE TEST SEQUENCE portion of this report; however, the following summarizes overall shortcomings:

1. System operation is sensitive to aircraft voltage fluctuation.

COOLING TOWERS AND THE ENVIRONMENT

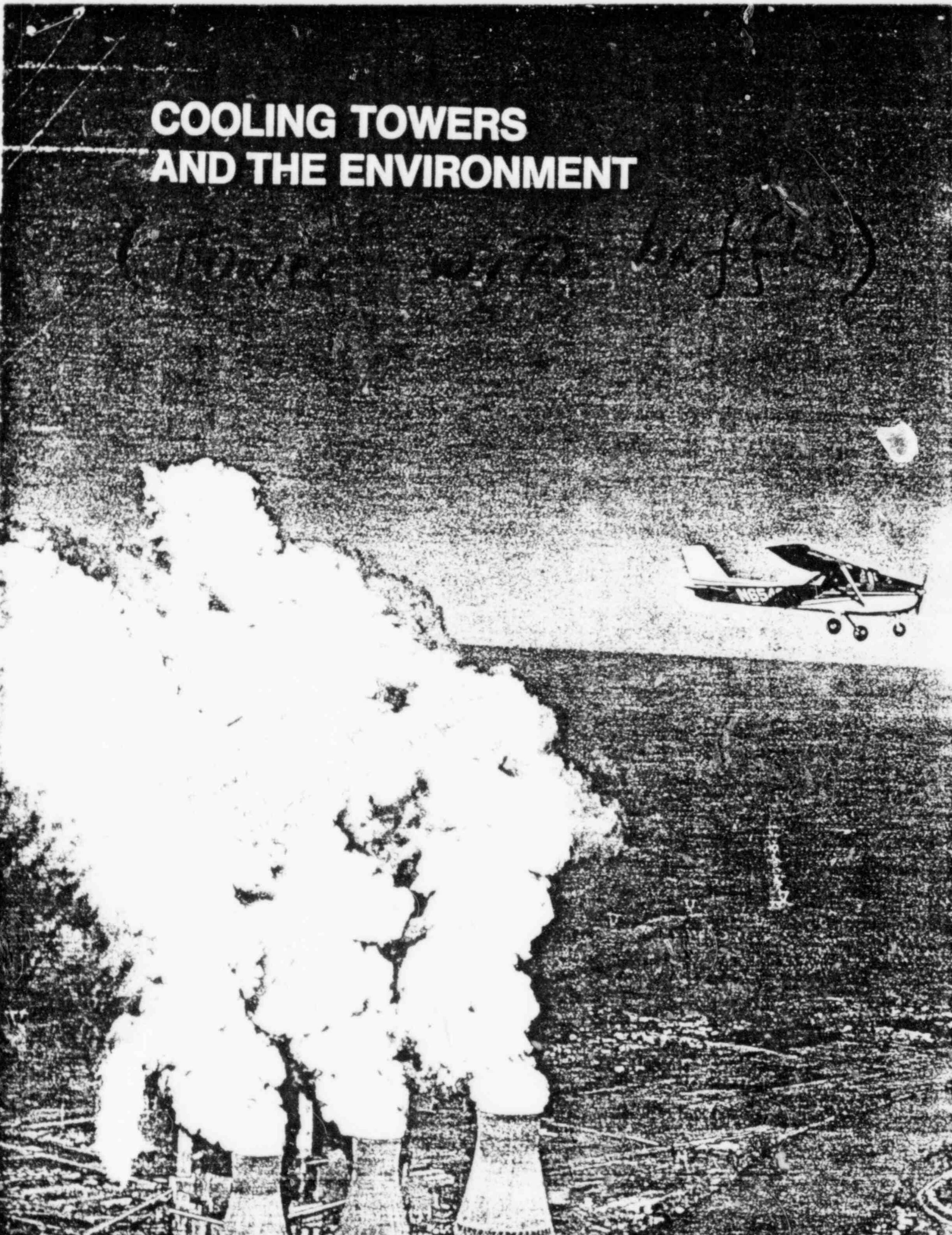

Figure 3: Typical Short Plumes
April 11, 1974   2:25 p.m.

Especially during the midday hours plumes normally evaporate quickly. In this instance, with the air temperature at 68°F. and the relative humidity less than 30%, the Amos plumes dissipated within 200 feet of the tops of the towers.

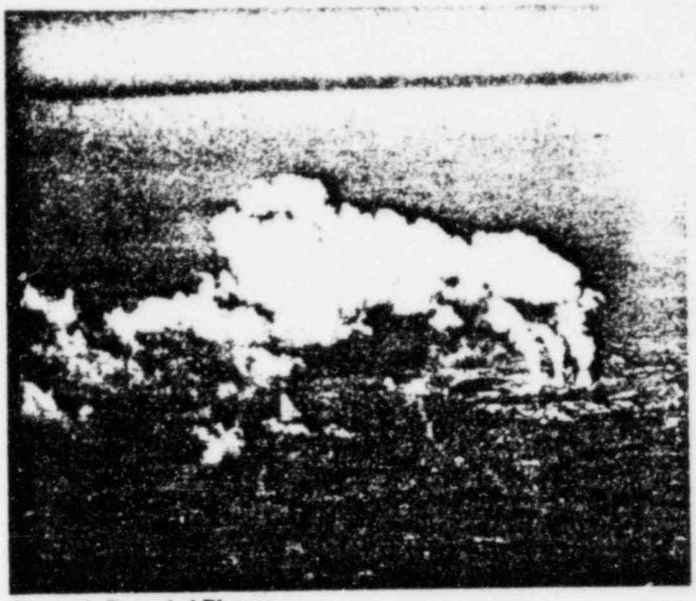

Figure 4: Extended Plumes
April 16, 1974   7:55 a.m.

The plumes from the Amos towers rose to a maximum height of 5,000 feet in this case and persisted for six miles. The air temperature at plume height was 28°F. and the humidity 55%.

Figure 5: Extr
February 15, 1

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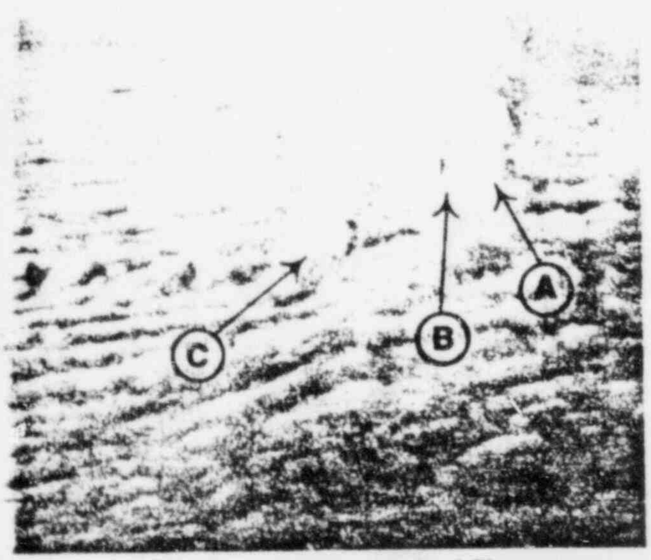


Figure 7: Cooling Tower and Stack Plumes Above Natural Fog
May 7, 1974   7:00 a.m.

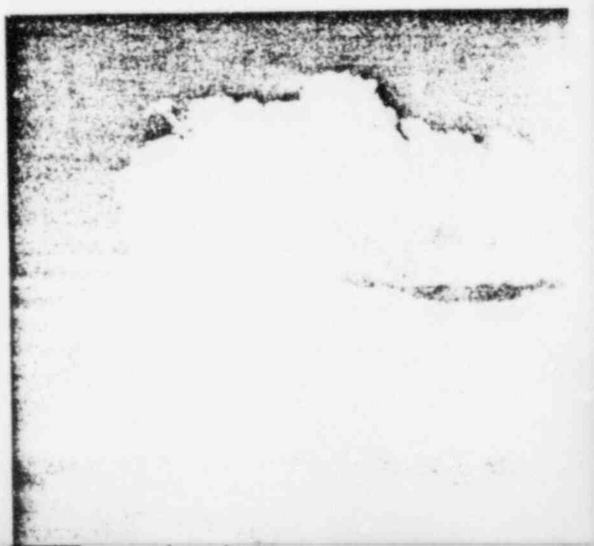
The plume from one Mitchell tower (A) and the stack plumes from Mitchell (B) and a nearby plant (C) rise thousands of feet above a deep layer of natural fog. The winds were light, the temperature 28°F. and the relative humidity 78% at plume altitude.

Figure 8: Plumes Merging with Natural Cloud Layer
January 29, 1974   9:30 a.m.

The trio of plumes from Amos rise 2,500 feet above ground and blend with the existing cloud layer. The temperature was 32°F. and the atmosphere saturated at the cloud level.

Figure 9: Tower Plume Rising Through a Natural Cloud Deck
January 25, 1974   12:46 p.m.

The converse of Figure 8, in which the Amos plumes break completely through the natural cloud deck at approximately 3,500 feet.



...ne
a.m.

...e Amos plumes rising almost vertically to 3,200 ...ne miles. The atmosphere was very stable with light temperature was 23°F. and the relative humidity 90% ...ume.

Figure 6: Plume Rising Above Natural Fc
May 28, 1974 7:04 a.m.

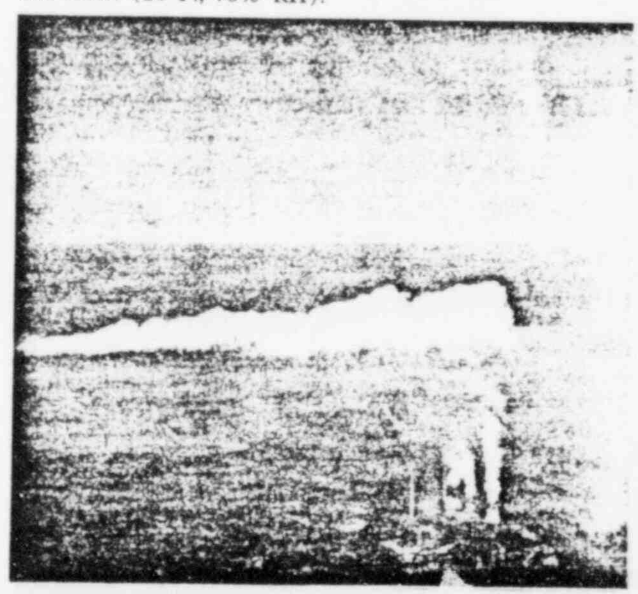
The single plume from one Amos unit rises above the blanket of natural fog which shrouds the valley. The winds were very light and the air relatively dry (35%) at the height of the tower top.

Figure 10: Isolated Cloud Formed From Tower Moisture
April 16, 1974 2:10 p.m.

The tower plumes (lower right) evaporate quickly in the relatively warm, dry air near the top of the tower (52°F., RH 33%), but the invisible moisture continues to rise and forms a new cloud 8,000 feet above ground, where the air is cool (34°F.).

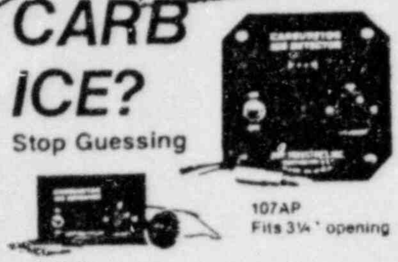
Figure 11: Shadowing Effect of Tower Plumes
February 15, 1974 1:15 p.m.

The shadow of the tower plumes is clearly visible over a large area north and west of the Amos plant. The base of the main plume is at 3,000 feet above ground, where the air is cold and moist (26°F., 78% RH).



CARB ICE?

Stop Guessing



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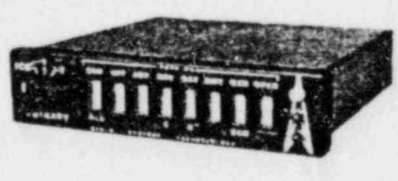

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38

Simple Detector Shows Forming of Ice in Venturi

by Alfred R. Puccinelli

STATISTICS CONCERNING AIRCRAFT accidents caused by engine failures due to carburetor icing are often misleading. Carb ice forms in a very underhanded manner. It can come on very rapidly, cause its sometimes lethal effects, and then disappear before the FAA NTSB team of accident investigators can detect it and report the true cause of a crash.

Many FAA accident reports are marked "Engine Failure Due to Unknown Causes." Accidents can be caused by water in the fuel tank and lines or failure of the engine or engine accessories, among other causes, but these can be readily identified during an accident investigation. Carb ice, however, can disappear within minutes after an accident occurs. The investigators may find only a few drops of water in the induction system and carburetor throat; they cannot report ice if only water is found. In addition, residual engine heat can cause the water to evaporate before the Feds arrive, further confounding the investigators.

It is logical to suspect that carb ice is much more prevalent than most aircraft

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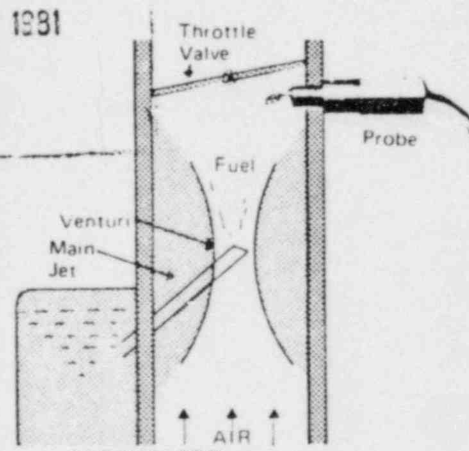

Carb Ice Detector probe is installed in the venturi area at the point where ice first begins to form in the carburetor—after the main nozzle and before the throttle valve.

owners/pilots realize, and that it has not been treated by the industry and the FAA in a manner that could eliminate icing as a major cause of engine failure.

As most pilots know, carb ice can form at almost any time, even at ambient temperatures higher than 70°fahrenheit, if the relative humidity and aircraft throttle setting are optimal for icing. What most pilots do not know and should be aware of is that frost forms in the throat of the carbu-

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PREVENTING INDUCTION ICING

The air taxi pilot was on an IFR flight plan from Roseburg to Bellingham, Washington. He carried one passenger in the Piper PA-28-181 Archer. Weather was 400 scattered, 1,100 broken, five in fog. Approaching Bellingham, the pilot initiated an ADF approach, which afforded the lowest minimums. He missed the approach and was cleared for a second one. On this attempt, he carried three notches of flaps and he kept 2,000 rpm. Three miles short of the field, the engine started cutting out, then quit. He applied carburetor heat, but it was too late. The plane crashed into the trees well short of the runway.

In looking into the accident, National Transportation Safety Board field investigators questioned local flight instructors and discovered that many were telling their students that carburetor heat is unnecessary if rpm is kept up to 2,000 during reduced throttle operations. The use of carb heat *after* the engine quit was advocated. NTSB also turned up the fact that at least one GADO, in Montana, has been failing many students on their private pilot checkrides for not using carburetor heat on the flight.

Pilots should understand the different types of icing that can affect engine operation and how to prevent them. Despite the fact that the dangers of icing and the prevention of those hazards have been documented for some time, apparently not all pilots are comprehending the cure.

During a five-year period, FAA says, there was a total of 360 general aviation accidents involving induction icing as a probable cause/factor. Forty fatalities, 160 injured people and 47 aircraft destroyed, and 314 others substantially damaged - all because of induction icing which can be prevented. In addition, FAA suspects that some accidents blamed on undetermined engine failure could have been caused by induction icing. And contrary to popular belief, most carb ice accidents occur during cruise or climb. In virtually all cases induction icing accidents can be attributed to the pilot.

Impact induction ice, which can affect an engine with injection-type pressure carburetors as well as ones with float bowl carburetors, forms when moisture-laden air, at temperatures below freezing, strikes air scoops, heat or alternate air valves, intake screens and protrusions in the carburetor. Flying in snow, sleet, rain or clouds is conducive to the formation of this type of icing.

Fuel ice forms at and downstream from the point where fuel is mixed with the incoming air. It occurs when the moisture in the air is cooled by the vaporization of the fuel. If ice is allowed to build up in the walls of the induction passages, it can throttle the engine. Visible moisture in the air is not necessary to cause fuel icing, which can occur at temperatures from 32° to 100° F, and with a relative humidity of 50 percent or more. It should be noted, however, that the likelihood of icing increases as the temperature decreases(down to 32° F) and as the humidity increases. Fuel icing is most likely to occur with temperatures below 70° F and relative humidity above 80 percent.

Throttle ice is formed at or near a partially closed throttle, as in a cruise power setting. In engines with float-type carburetors, throttle icing usually occurs along with fuel icing, compounding the problem.

All three types of icing can cause loss of power, because the flow of the fuel-air mixture to the engine is restricted. Carburetor heat or alternate air should be used when icing conditions are present to prevent ice buildup. Fast-forming ice may reduce the amount of heat available, and the use of partial heat may be worse than not using it at all.

In aircraft with smaller engines, with no carburetor air or mixture temperature instrumentation, full carburetor heat should be applied as necessary. Carb heat should be shut off for full power operations such as takeoffs and emergency go-arounds. Leaving the heat on could seriously reduce the amount of power available and could damage the engine.

Just as you should automatically apply carburetor heat before throttling back for descent, you should automatically turn off carb heat when applying full power for a go-around or a touch-and-go. Carb heat should be on the pretakeoff checklist to test its effectiveness - the power should drop on runup when carb heat is applied. If the relative humidity is above 50 percent and the temperature is below 70° F, apply carburetor heat immediately before takeoff, as ice may have accumulated during taxi. Don't leave it on, however.

If a power loss is observed, apply full heat or alternate air before disturbing the throttle. If the ice remains, gradually advance throttle to full power rate to produce as much heat as possible.

FAA advisory circular 60-9 **Induction Icing - Pilot precautions and procedures** contains full details. This publication is available free by writing to: Department of Transportation Publications Section, TAD 4431 Washington, D.C. 20590.