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MEASUREMENT OF ICE ACCRETION USING ULTRASONIC PULSE ECHO TECHNIQUES

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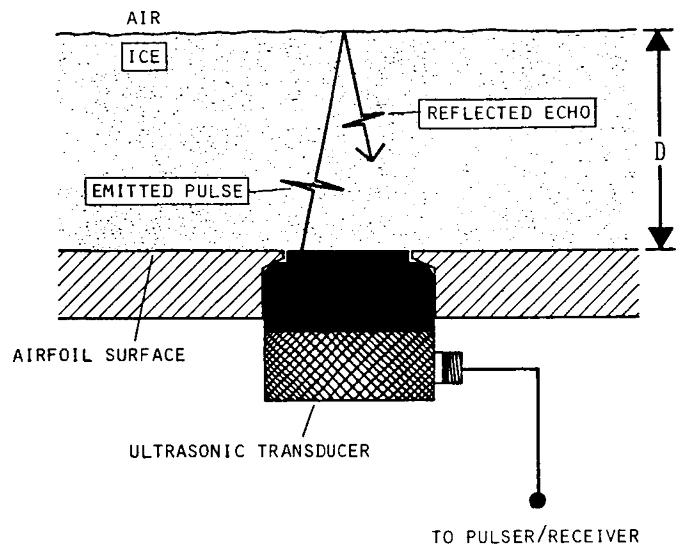
This figure shows the need for ice accretion measurement.*

- OPERATIONAL (ROTARY AND FIXED WING)
  - AVOIDANCE & ESCAPE (REQUIRES ICING RATE)
  - C & W
  - MANAGEMENT OF ICE PROTECTION SYSTEMS
    - BOOTS
    - ELECTROTHERMAL

- RESEARCH
  - SUPPORT ICE MODELING EFFORTS
    - TIME DEPENDENCE
  - DOCUMENT METEROLOGICAL CONDITIONS
  - CERTIFICATION

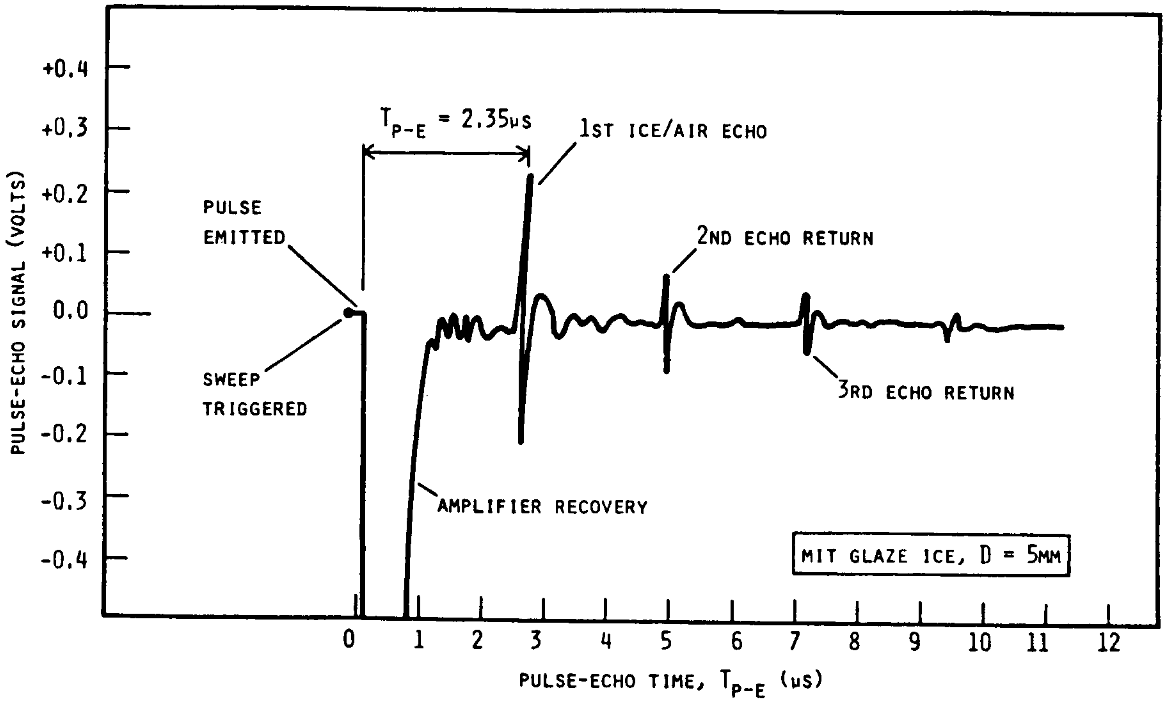
*Original figures in this paper not available at time of publication.

This figure depicts the basic concept of ultrasonic pulse-echo measurement. The thickness of the ice is related to the pulse-echo time T_{P-E} by the speed of sound C.

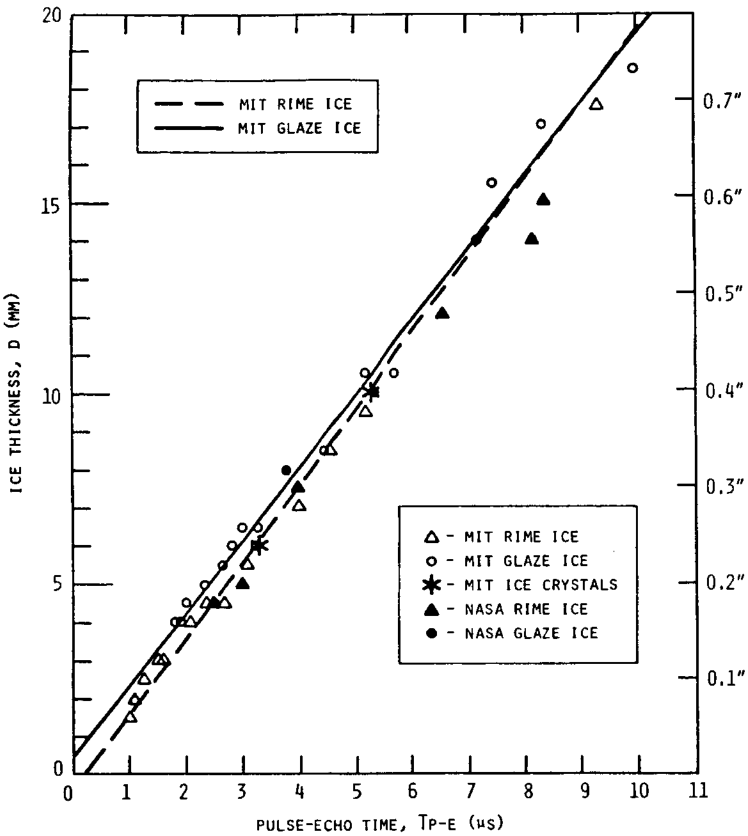


$$D = \frac{C_{ICE} T_{P-E}}{2}$$

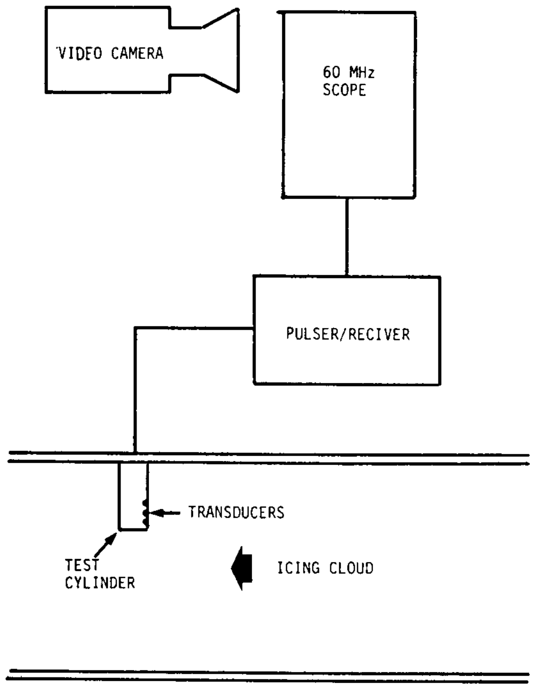
This figure shows a typical pulse-echo signal, showing multiple echoes from the ice-air interface.



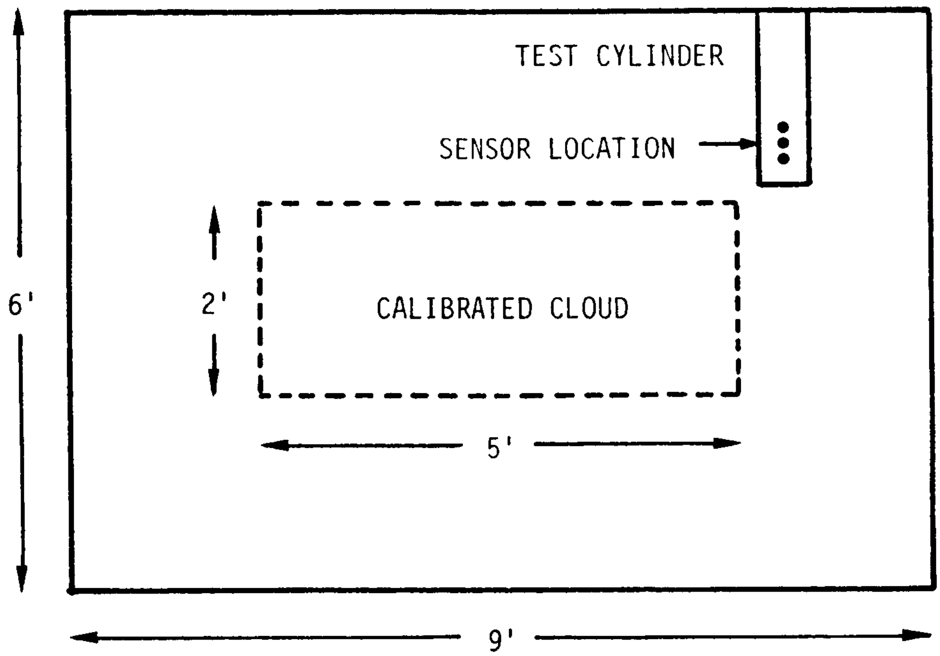
The results of static calibration tests on a variety of NASA and MIT ice samples are shown in this figure. The speed of sound appears to be insensitive to ice type, with a value of approximately 3.8 mm/sec.



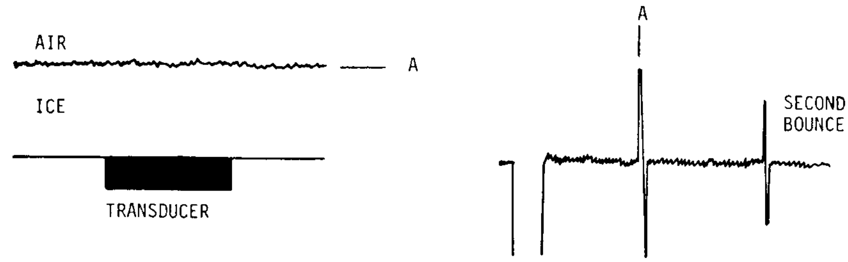
This figure is a schematic of the setup for ice accretion tests in the Icing Research Tunnel (IRT). Several transducers were mounted on a 4-in. diameter cylinder in the IRT. Echo patterns were videotaped during icing exposures under a variety of conditions.



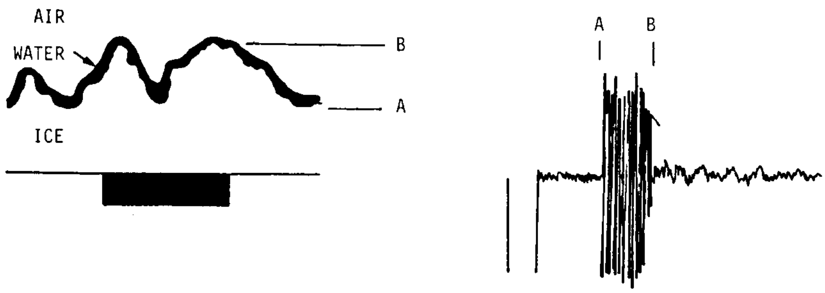
The location of the test cylinder in the IRT is shown in this figure. It should be noted that the cylinder is not in the calibrated region of the tunnel.



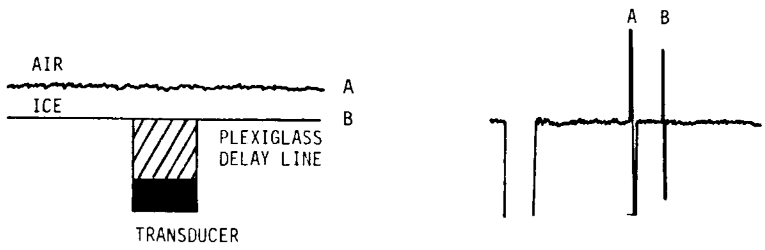
This figure shows typical echo patterns for rime and glaze ice. The echo is broadened in the glaze case due to the irregularity of the air-ice interface.



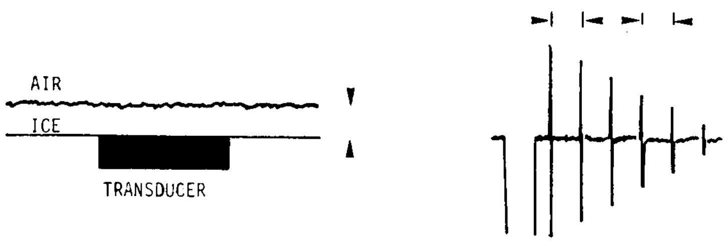
RIME ICE



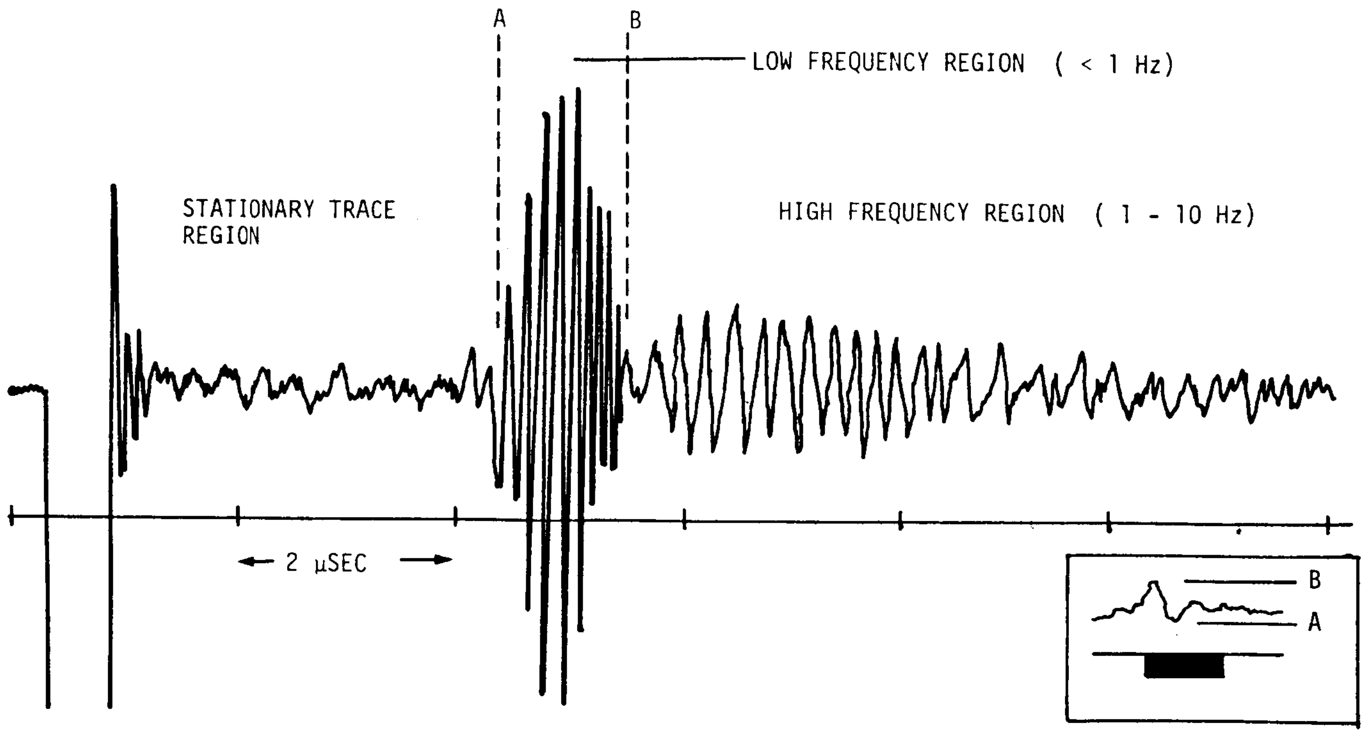
This figure shows typical echo patterns for thin ice samples in which the pulse-echo time is shorter than the recovery time of the amplifier. The echo signal can be delayed by use of a delay line. For normal transducers, the pulse-echo time can be inferred from the time between multiple echoes.



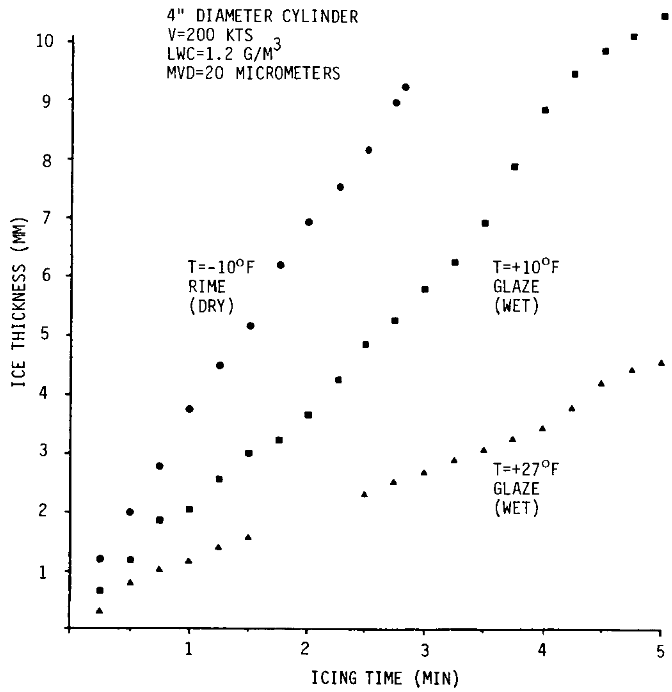
DELAY LINE TRANSDUCER



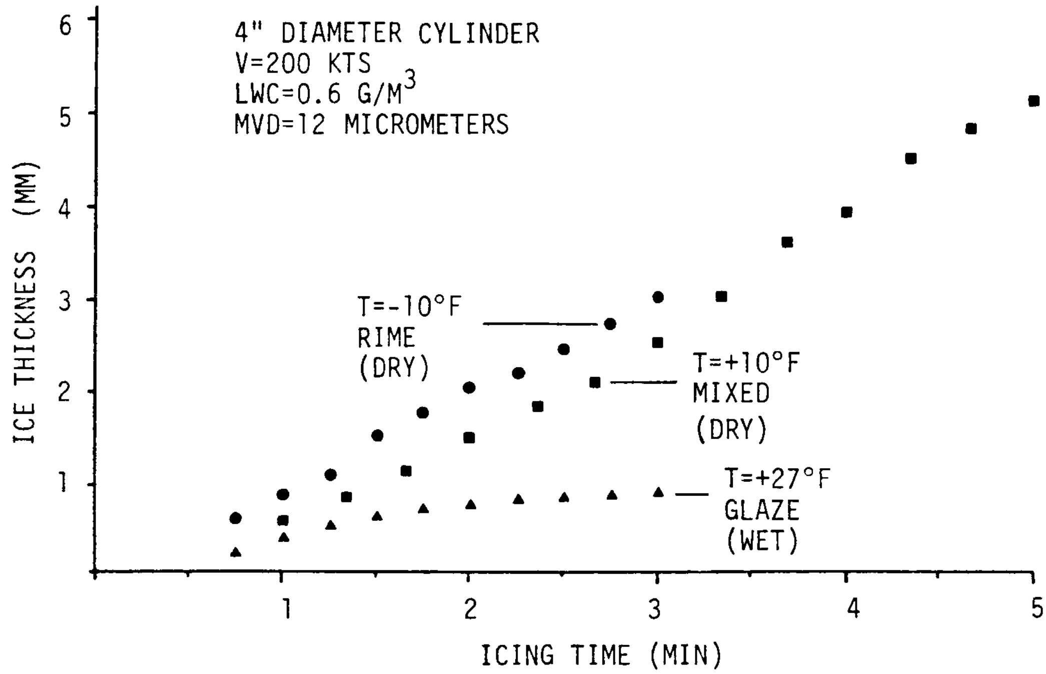
A typical echo pattern for glaze ice with surface water present is shown in this figure. Surface waves in the water cause fluctuations in the echo pattern. This technique should allow accurate determination of the conditions under which runback occurs.



This figure shows ice thickness measured by the ultrasonic technique versus icing time for heavy icing conditions.



Shown below is the ice thickness measured by the ultrasonic technique versus icing time for light icing conditions.



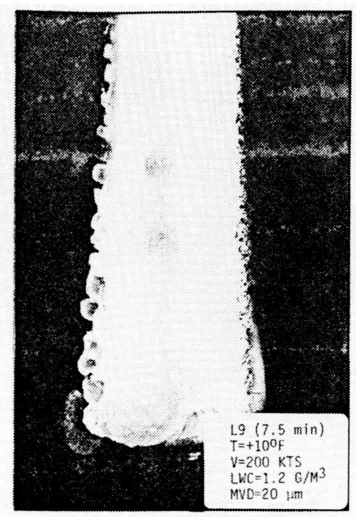
This table summarizes the icing rates measured in the IRT, as well as the presence or absence of surface water.

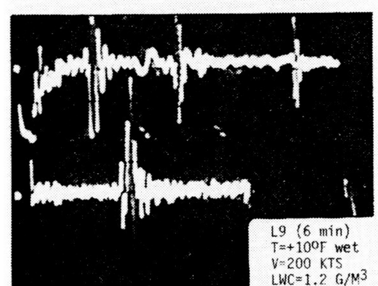
ICING RATES FOR A 4" CYLINDER IN THE IRT

V=200 KTS (CYLINDER WAS NOT IN CALIBRATED REGION)

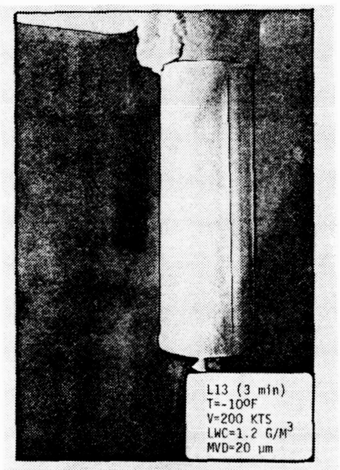
TEMPERATURE	+27°F	+10°F	-10°F
HEAVY ICING CONDITIONS	0.75 MM/MIN	2.10 MM/MIN	3.15 MM/MIN
LWC=1.2 G/M^3	GLAZE	GLAZE	RIME
MVD=20 μM	WET	WET	DRY
LIGHT ICING CONDITIONS	0.55 MM/MIN	1.05 MM/MIN	1.05 MM/MIN
LWC=0.6 G/M^3	GLAZE	MIXED	RIME
MVD=12 μM	WET	DRY	DRY

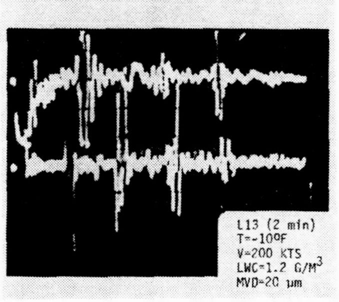
This figure shows the ice growth and echo patterns for a glaze ice run. The top trace is the delay line echo. The bottom trace is the normal transducer echo.





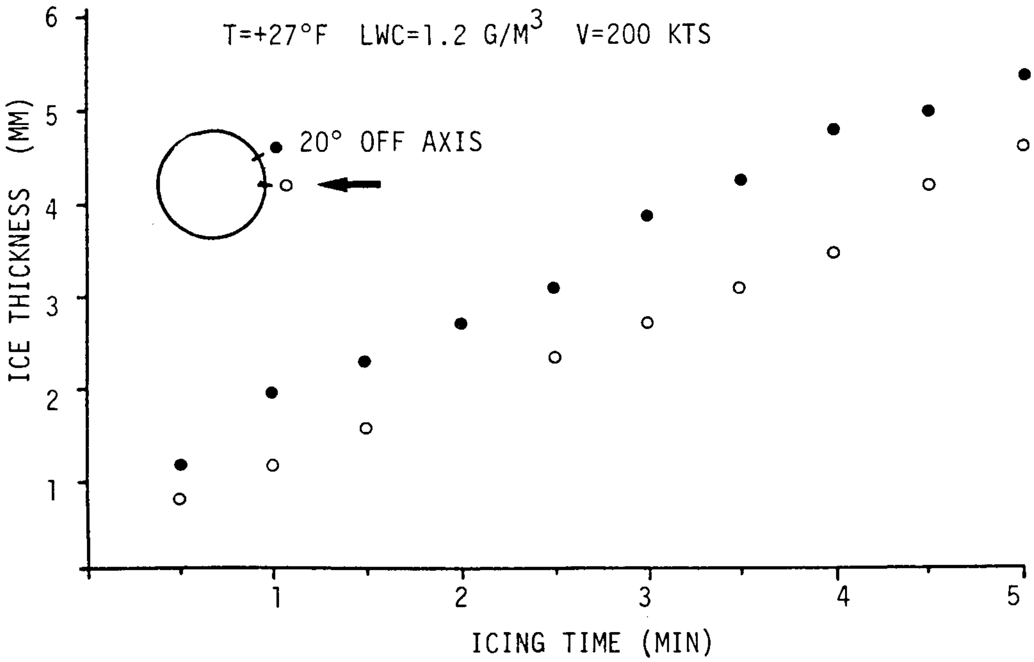
This figure shows the ice growth and echo patterns for a rime ice run. The top trace is the delay line echo. The bottom trace is the normal transducer echo.





ORIGINAL PAGE IS OF POOR QUALITY

This figure is an example of ice thickness versus time for a horn ice growth.



This figure shows ice thickness versus icing time for the multiple-echo resulting from an ice ridge growing over the transducer in glaze conditions.