SAE INTERNATIONAL

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CALCULATION-EXPERIMENTAL RESEARCH ON METHODICAL ISSUES OF PROVODING TESTS OF AVIATION TECHNOLOGY ELEMENTS IN SLD CONDITIONS AT HIGH FLOW SPEEDS

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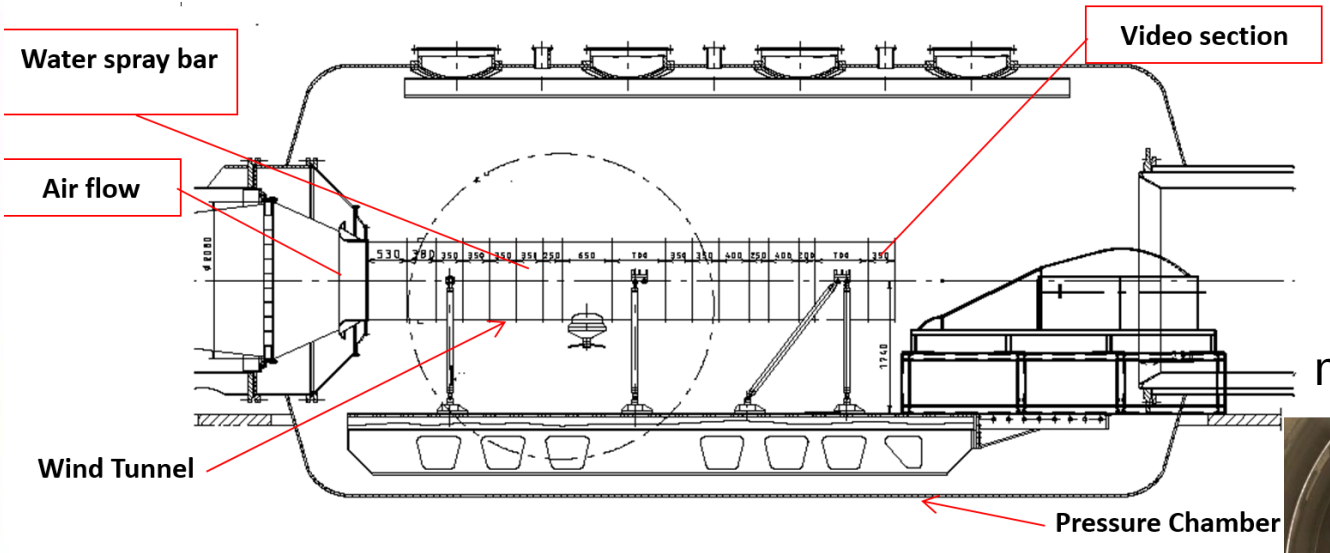
FLIGHT SPEED RANGES

- For helicopter airframe elements:
  60 ÷ 290 km/h (16.7 ÷ 80.5 m/s)
- For helicopter blades: 154 ÷ 160 m/s
  (for specific sections of blades)

- For airframe elements:
  438 ÷ 784 km/h (121.7 ÷ 217.8 m/s)

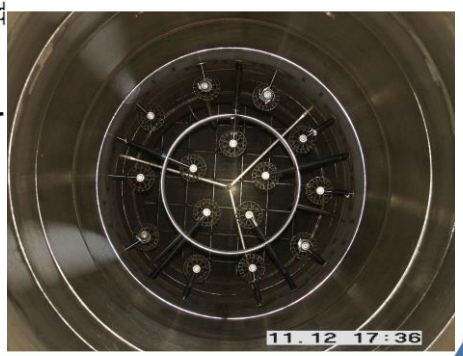
CIAM C-2 TEST CELL FOR MODELING ICING CONDITIONS



Scheme of the C-2 CIAM test cell with wind tunnel

IWT diameter Ø1.02 m

Water spraybar manifold 15 injectors



CALIBRATION TYPES

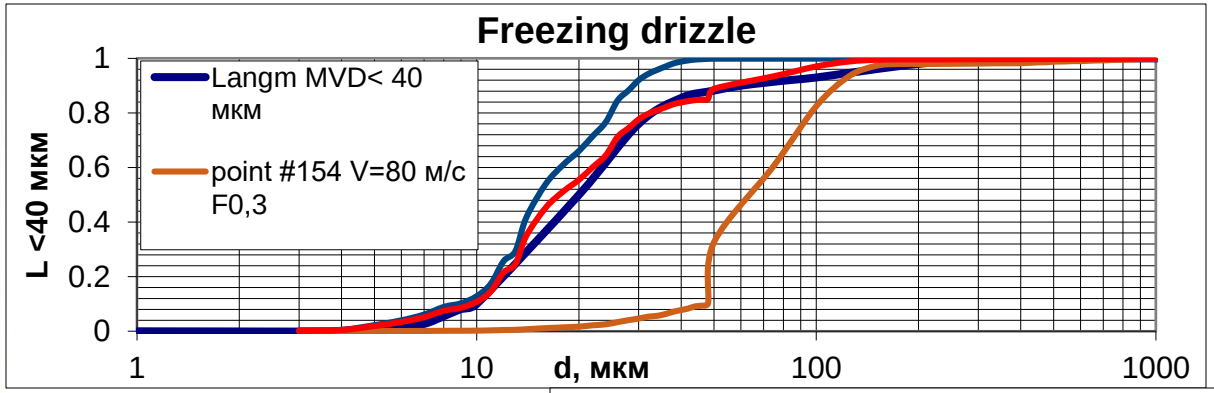
Aerodynamic calibration:

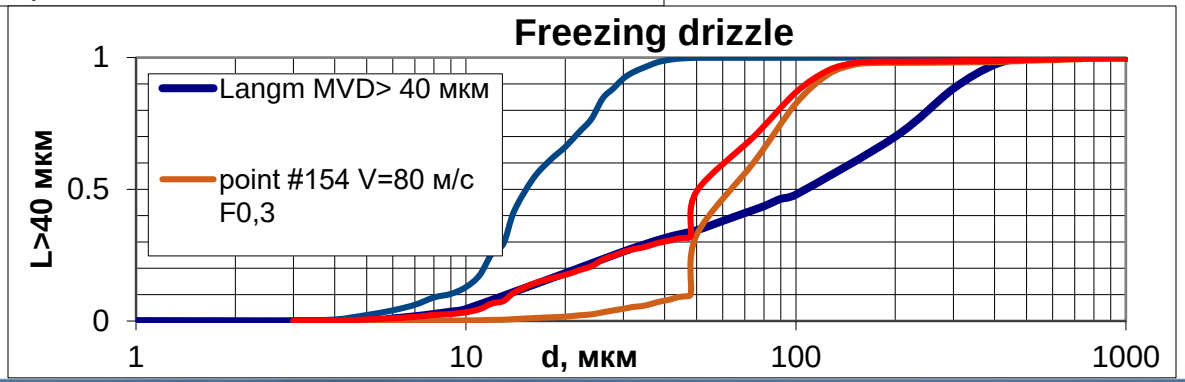
- maintenance of uniform potential flow core;
- determination of pressure pulsation level;
- determination of object impact on airflow.

Calibration of ice conditions:

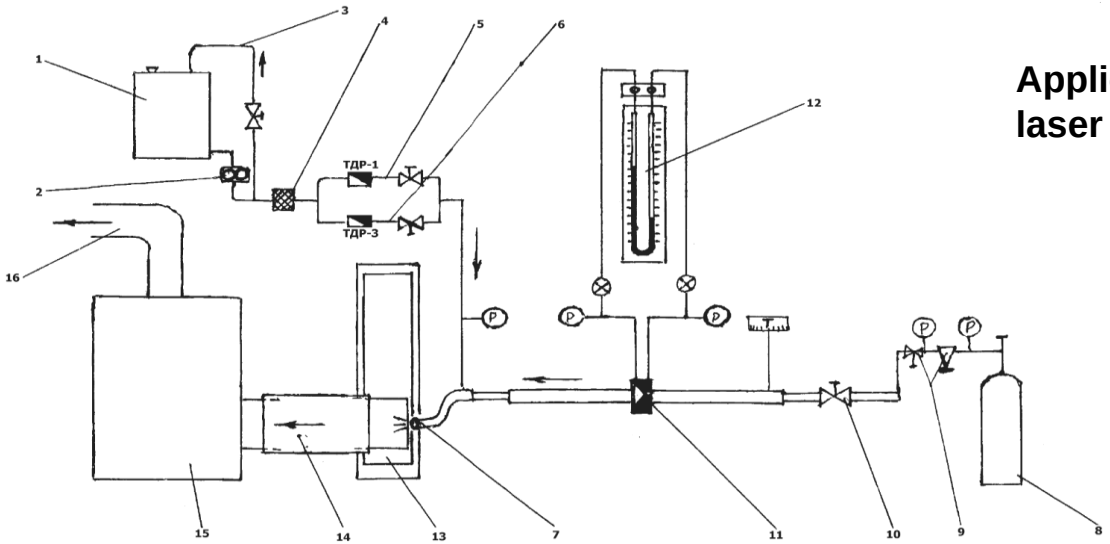
- injectors calibration;
- maintenance of icing cloud uniformity of the flow core;
- determination of droplets supercooling extent;
- LWC and MVD calibration.

Obtaining large drops in the airflow





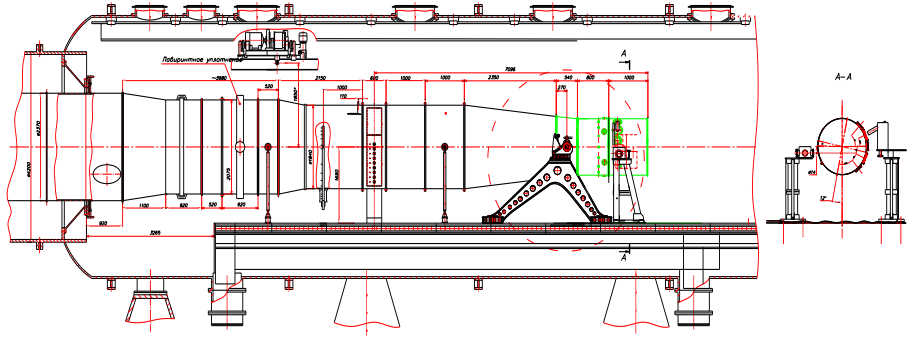
MVD DROPLET SIZE MEASUREMENT METHODS



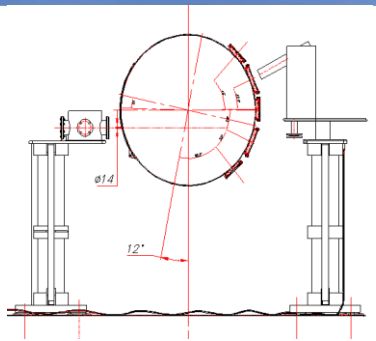
Application of MASTERSIZER-X laser analyzer of droplets size

1 – water tank (40 liters), 2 – pressure pump, 3 – by-pass line with tap, 4 – filter (20 μm), 5 – measuring section with TDR-1 flowmeter and shut-off valve, 6 – measuring section with ТДР-3 flowmeter and shut-off valve, 7 – calibrated injector, 8 – compressed air bottle (40 liters), 9 – reducer with valve, 10 – metering valve, 11 – metering diaphragm, 12 – differential manometer, 13 – measuring section («MALVERN INSTRUMENT» particle size analyzer, «MASTERSIZER-X» make), 14 – transition section , 15 – moisture separator of «Cyclon»-type, 16 – suction line.

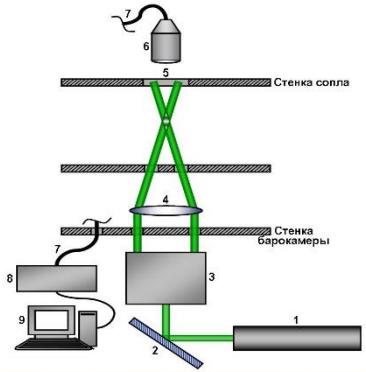
PHASE-DOPPLER PARTICLE ANALYZER



Rig's diagram with PDPA



PDPA optical scheme

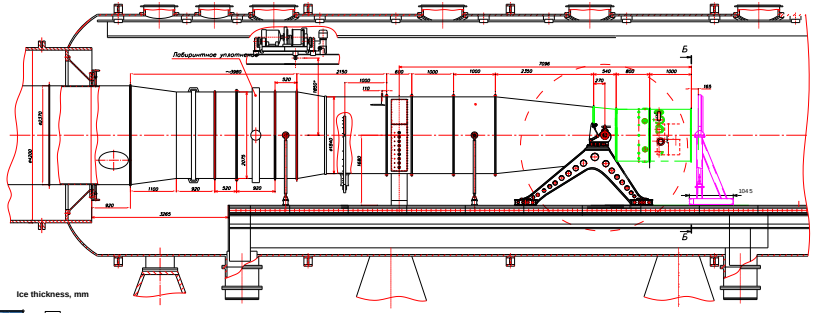


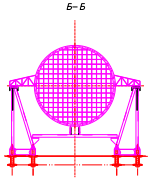
- Laser
- Mirror
- Forming Optics
- Transferring Lens
- Window in a wall of a Rig
- Fibre-optical reception block
- Fibre-optical cable
- Doppler's signal processor
- Computer

ICING CALIBRATION

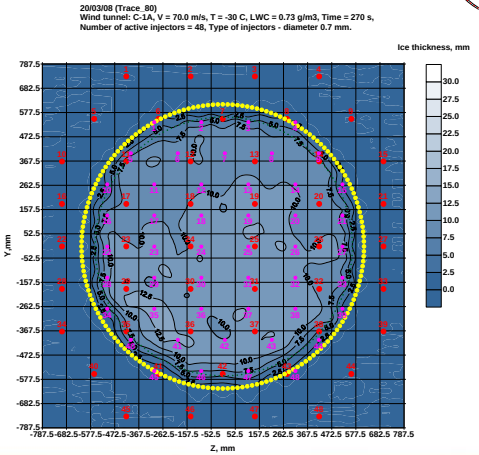
LWC cloud uniformity

Ice accretion map





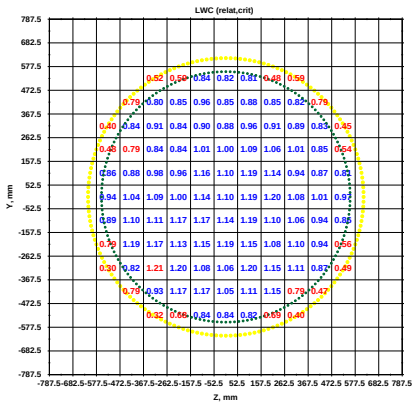
Local relative ice thickness



D injector = 0,7 mm

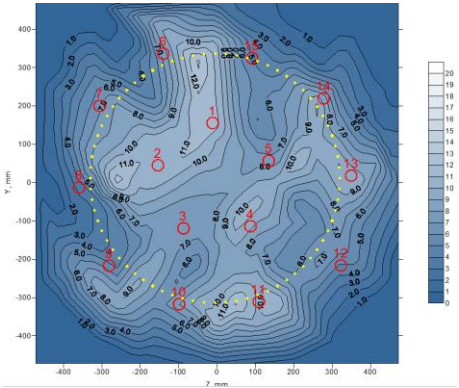
V = 70 m/s

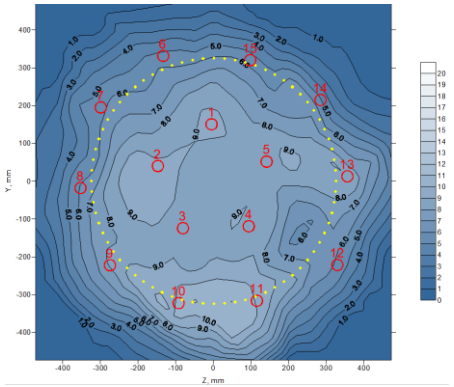
LWC = 0,73 g/m3



Evaluation of the icing cloud uniformity

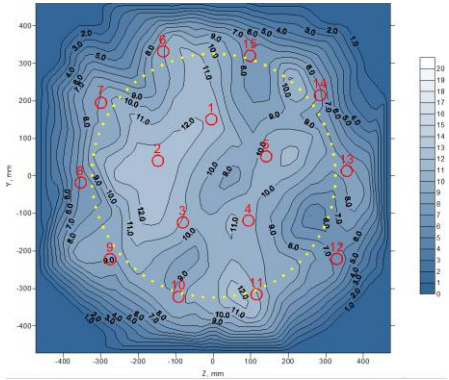
V=80 m/s, OAT=-20ºC,
LWC=0,4 g/s,
Dnozzle=0,7 mm





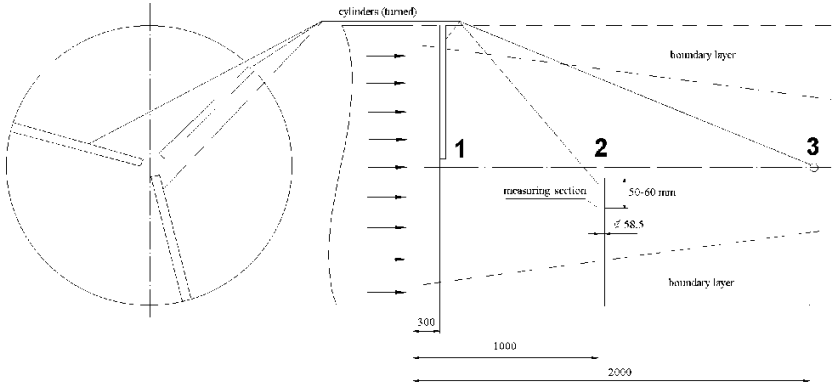
V=20 m/s, OAT=-15ºC,
LWC=0,6 g/s,
Dnozzle=0,3 mm

V=80 m/s, OAT=-20ºC,
LWC=0,6 g/s,
Dnozzle=1,2 mm



Evaluation of the droplets supercooling degree

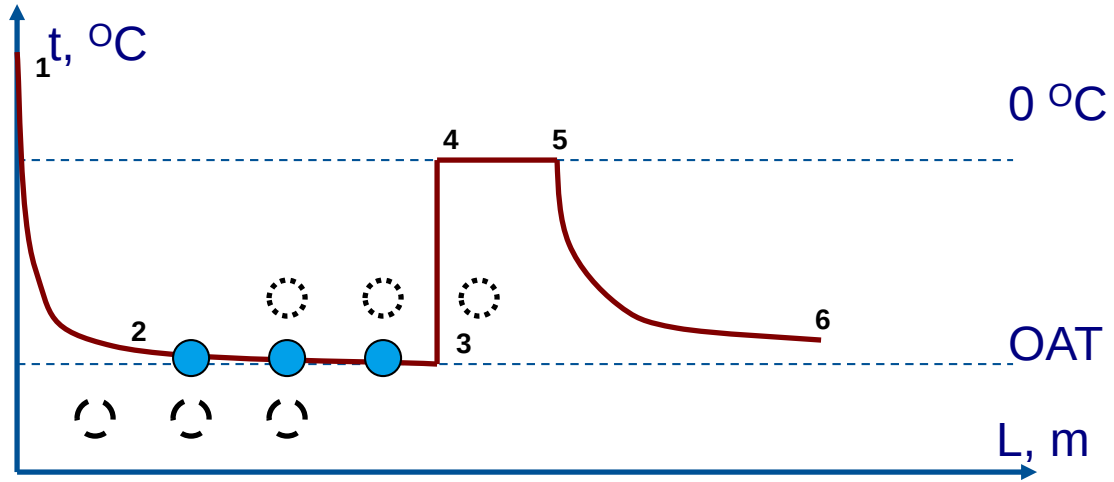
The goal is to confirm that droplets impinge on the object of study at a temperature close to the temperature of the main air flow in a supercooled state.



3-cylinder calibration test layout

The appearance of the C-2 test cell

ESTIMATION OF DROPLETS SUPERCOOLING EXTENT

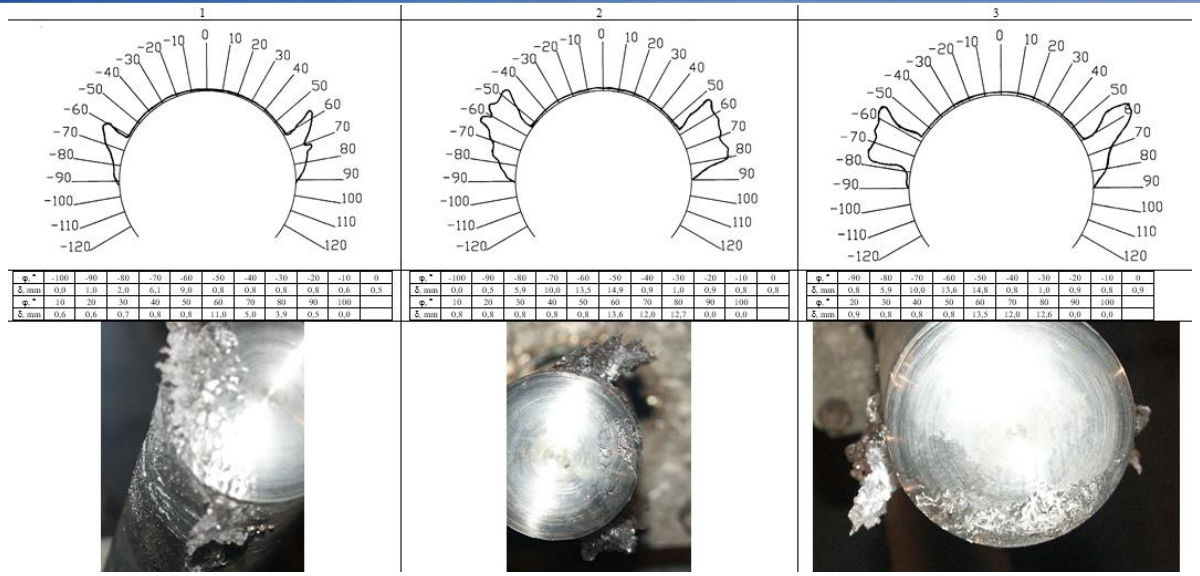


ICE FORMS ON CYLINDERS

V = 80.3 m / s

OAT = -1.3 ºC

MVD = 19 mkm



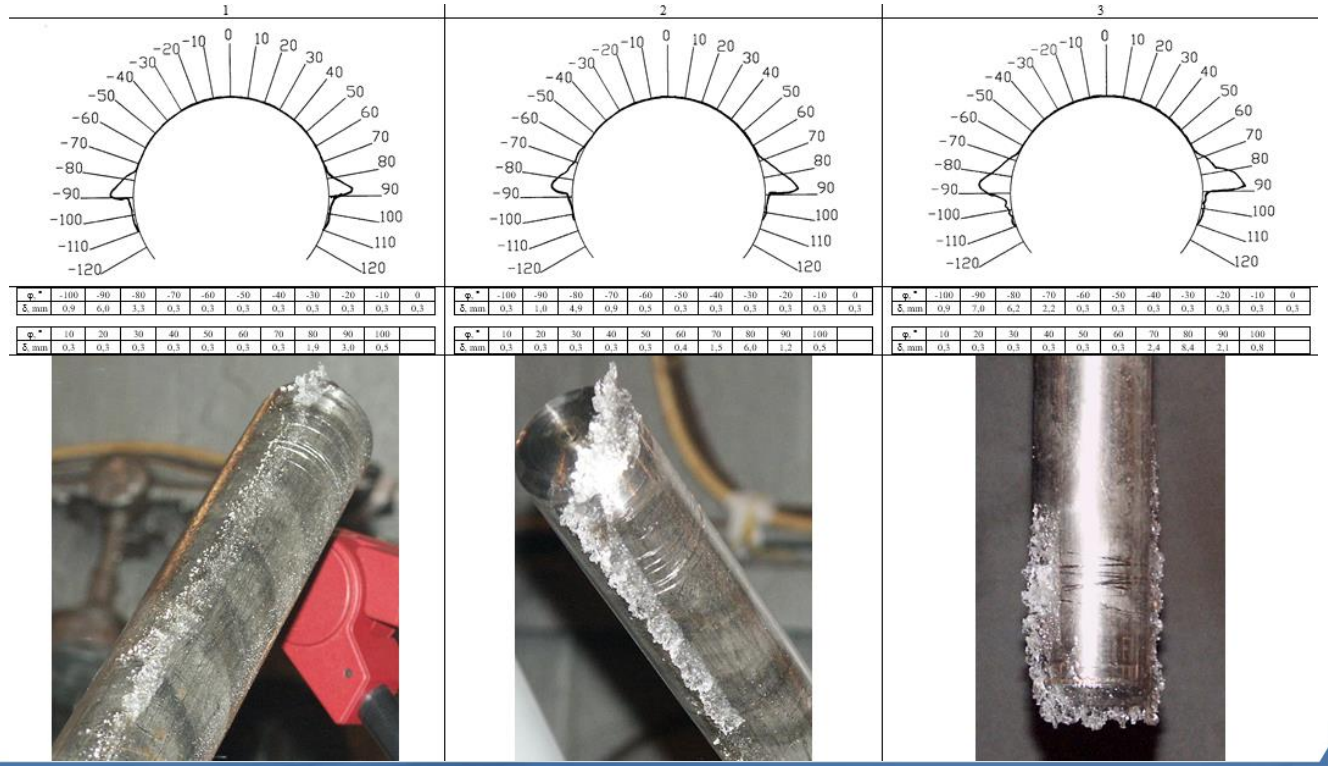
№	V, м/с	Z, км	OAT, ^{O}C	LWC,г/м^3	MVD, мкм	TIME, с	D_{ing}, мм
234	80,3	1,2	-1,3	0,9	19,3	30’40’’	1,2
237	80,3	1,2	-1,2	0,84	37,2	36’10’’	0,7
232	80	1,2	-4,7	0,52	38	12’	0,7
235	41,7	1,2	-4,5	0,84	23,15	13’	0,7

ICE FORMS ON CYLINDERS

V = 80.3 m / s

OAT = -1.2 ºC

MVD = 37 mkm



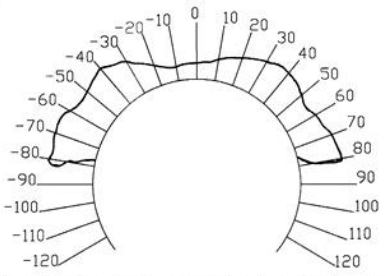
ICE FORMS ON CYLINDERS

V = 80 m / s

OAT = -4.7 ºC

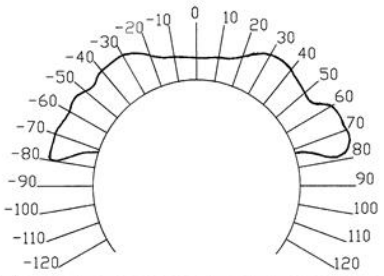
MVD = 38 mkm

1

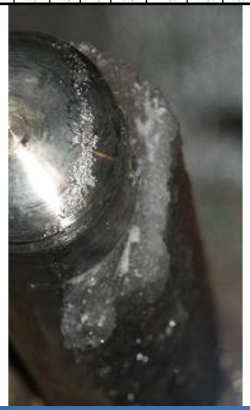


Φ, °	-100	-90	-80	-70	-60	-50	-40	-30	-20	-10	0
δ, mm	0,0	0,0	13,0	12,9	12,0	10,9	13,0	10,2	6,0	4,0	4,4
Φ, °	10	20	30	40	50	60	70	80	90	100	
δ, mm	6,0	8,0	10,0	11,0	9,2	9,1	11,0	12,0	0,0	0,0	

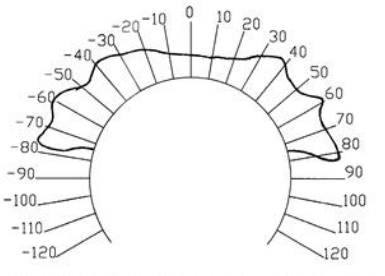
2



Φ, °	-100	-90	-80	-75	-70	-60	-50	-40	-30	-20	-10	0
δ, mm	0,0	0,0	12,5	13,0	13,0	12,0	11,8	12,3	12,5	9,0	7,0	6,0
Φ, °	10	20	30	40	50	60	70	75	80	90	100	
δ, mm	6,8	8,9	12,7	12,5	10,7	14,8	16,0	16,0	0,0	0,0	0,0	



3



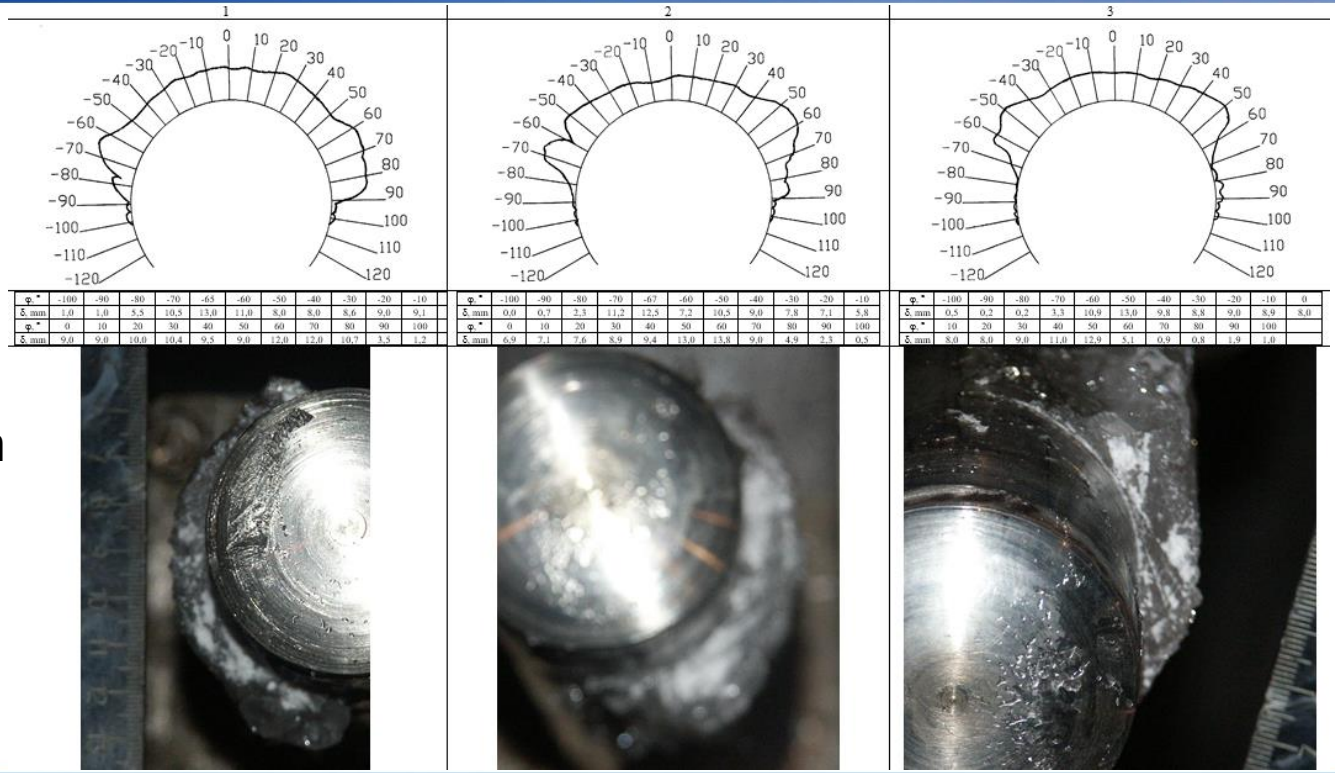
Φ, °	-100	-90	-80	-77	-70	-60	-50	-40	-30	-20	-10	0
δ, mm	0,0	0,0	0,0	17,0	14,9	16,8	12,0	13,9	12,0	10,2	7,1	6,3
Φ, °	10	20	30	40	50	60	70	80	82	90	100	
δ, mm	6,0	7,8	11,6	13,7	11,0	15,0	12,5	14,5	14,7	0,0	0,0	

ICE FORMS ON CYLINDERS

V = 41.7 m / s

OAT = -4.5 ºC

MVD = 23 mkm



φ, °	-100	-90	-80	-70	-65	-60	-50	-40	-30	-20	-10
δ, mm	1,0	1,0	5,5	10,5	13,0	11,0	8,0	8,0	8,6	9,0	9,1
φ, °	0	10	20	30	40	50	60	70	80	90	100
δ, mm	9,0	9,0	10,0	10,4	9,5	9,0	12,0	12,0	10,7	3,5	1,2

φ, °	-100	-90	-80	-70	-67	-60	-50	-40	-30	-20	-10
δ, mm	0,0	0,7	2,3	11,2	12,5	7,2	10,5	9,0	7,8	7,1	5,8
φ, °	0	10	20	30	40	50	60	70	80	90	100
δ, mm	6,9	7,1	7,6	8,9	9,4	13,0	13,8	9,0	4,9	2,3	0,5

φ, °	-100	-90	-80	-70	-60	-50	-40	-30	-20	-10	0
δ, mm	0,5	0,2	0,2	3,3	10,9	13,0	9,8	8,8	9,0	8,9	8,0
φ, °	10	20	30	40	50	60	70	80	90	100	
δ, mm	8,0	8,0	9,0	11,0	12,9	5,1	0,9	0,8	1,9	1,0	

THANK YOU FOR ATTENTION