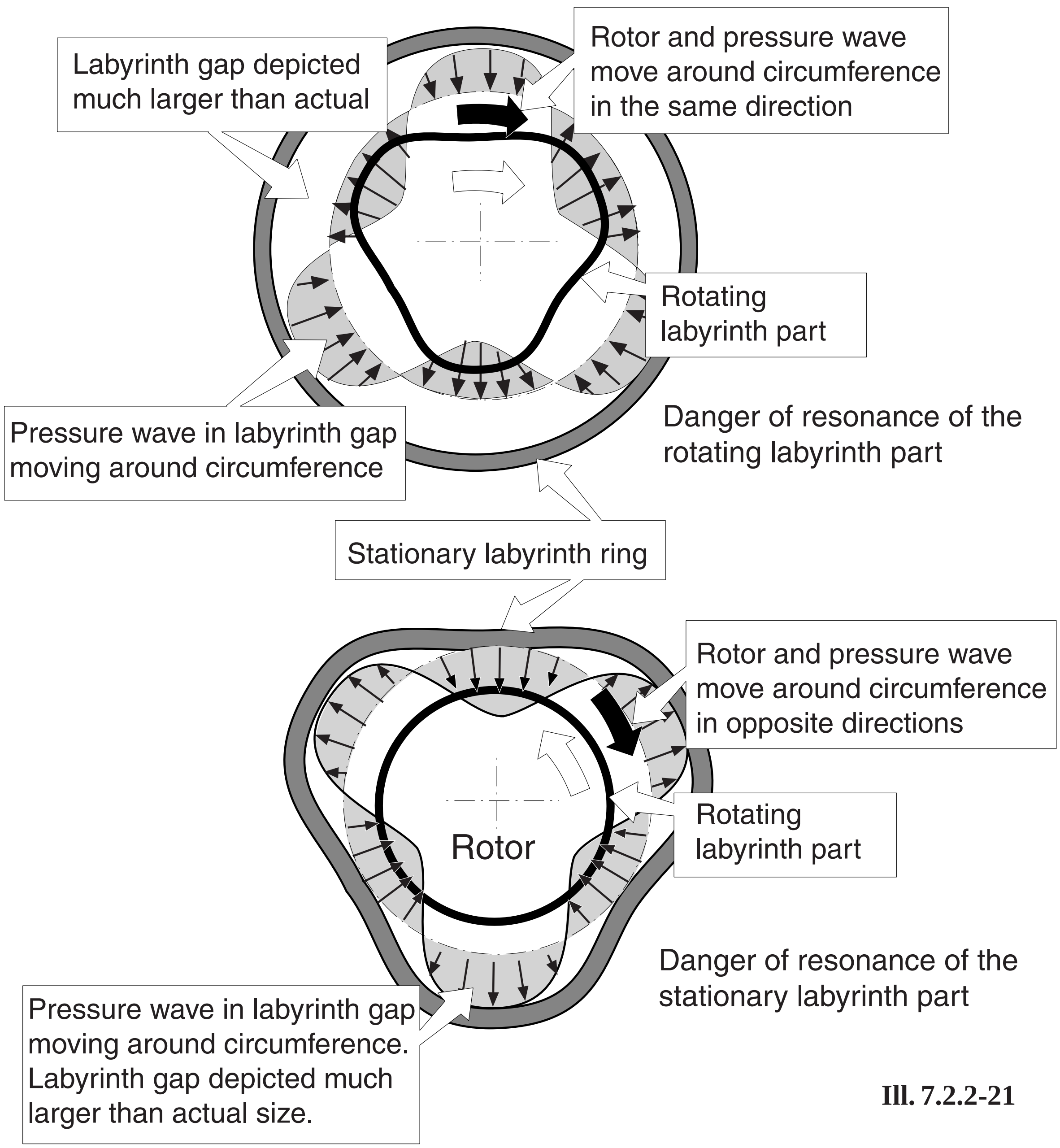
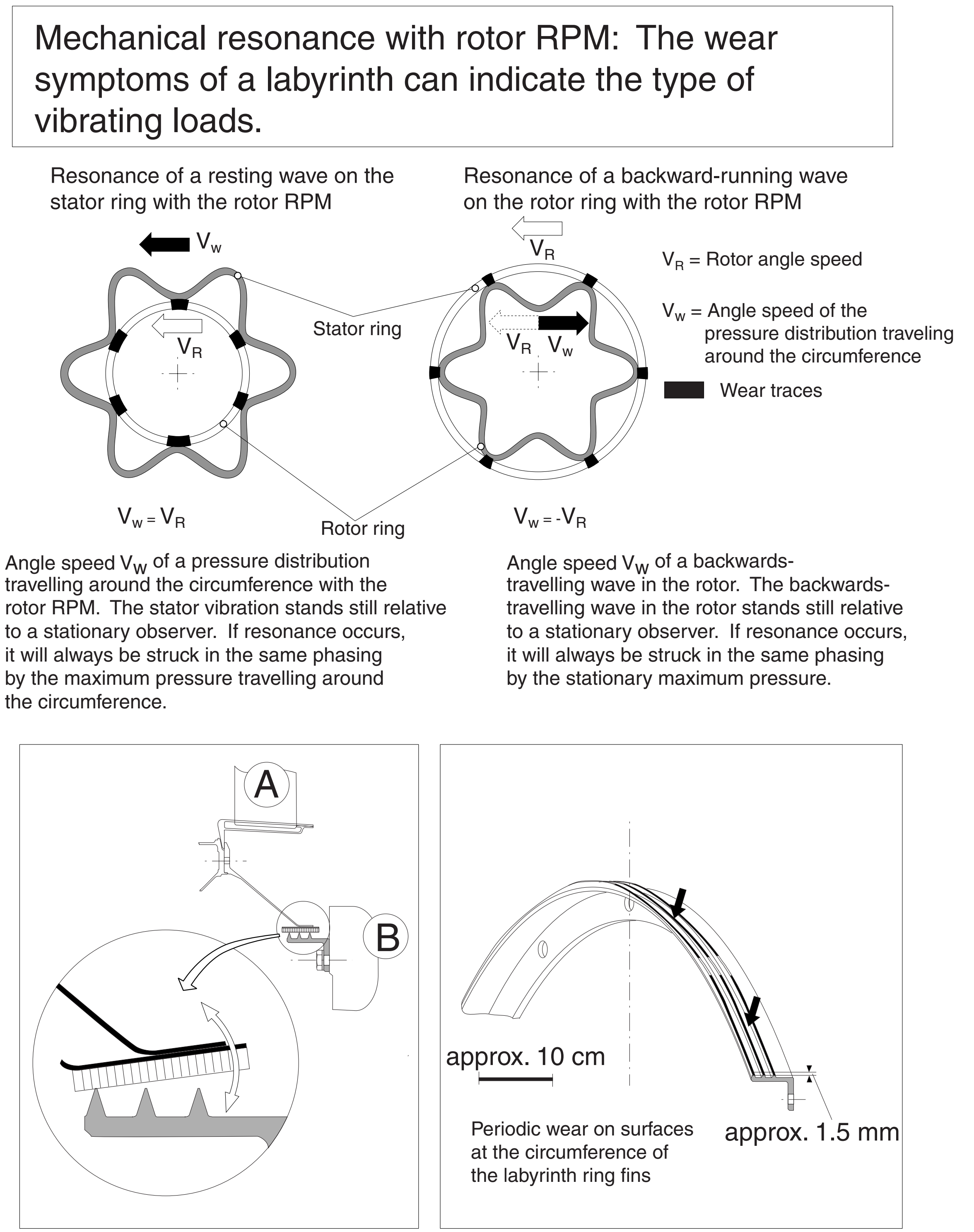
Mechanical resonance with the acoustic inciting frequency: the circumferential direction of the gas pressure wave and the rotor determines which parts are endangered by the resonance.



Ill. 7.2.2-21

Description of Ill. 7.2.2-21 on previous page.



Ill. 7.2.2-22

Ill. 7.2.2-22: *Labyrinth vibrations can leave typical periodic wear patterns of the rubbing surfaces along the circumference (bottom diagram, compare Ill. 7.2.2-29). For this to happen, the antinodes of one ring must remain stationary re-*

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lative to the other ring. This makes it possible to identify labyrinth vibrations on basis of the wear patterns. Depending on whether the vibration moved in (top left diagram) or against (top right diagram) the rotating direction of the inner ring, ***wear marks*** *can be found evenly spread around the circumference of the inner ring or the static outer ring (bottom diagrams, see Ill. 7.2.2-21). The number of wear marks around the circumference indicates the number of nodal diameters and therefore the type of damage-causing vibration (Ill. 7.2.2-20, Ref. 7.2.2-23).*
*The bottom left diagram depicts a typical labyrinth configuration in which the damage in the right diagram can occur. The causal mechanism is described in Ill. 7.2.2-19. "**A**" is a softly suspended static labyrinth ring, and "**B**" is the corresponding rotating labyrinth ring.*

Ill. 7.2.2-23 *(Ref. 7.2.2-12): This is a small turbofan engine used in ground-combat support aircraft and business jets. The depicted seal system is located at the forward side of the first high-pressure turbine disk. The inner seal is fastened on the low-pressure side, the outer seal is fastened on the high-pressure side. If they are sufficiently stiff, seals attached to the low-pressure side are usually safe from vibrations aeroelastically caused by the leakage flow. The damping wire of the inner labyrinth should also serve to prevent these vibrations. However, during a testing-rig trial during engine development, the front tooth of the inner labyrinth seal had a dynamic crack initiate (bottom right diagram with detail). In the first variation (top right diagram with detail), the damping wire was attached at the very front. Since this also resulted in problems, a change was made to the variation in the bottom left diagram.*
Tests of the variation in the bottom right diagram showed that, at various leakage rates, vibrations with three nodal diameters occurred in the inner seal (see Ill. 7.2.2-20). The pressure vibrations were in phase with the deflections of the rotating labyrinth ring. The tests also showed that ***seal rings which are only affixed on the high-pressure side can only be made to vibrate by the leakage air flow if the mechanical frequency of the ring was greater than the acoustic frequency of the air vibrations.***
Conversely, ***labyrinth rings affixed on the low-pressure side can only become instable if their mechanical frequency is lower than the acoustic frequency*** *(see Ill. 7.2.3-3).*
In order to stabilize the ring of the inner labyrinth, in addition to the damping ring, an inner damping bandage (held fast by centrifugal force) was also installed (bottom left diagram). This reduced the vibration stress by about 40%. This variant has proven itself over many years and millions of flight hours.