

## COOLANT PASSAGE HEAT TRANSFER WITH ROTATION

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One of the areas where technology is lacking is in predicting local heat transfer and local coolant flow conditions within coolant passages of rotating blades and particularly in blades that have multi-pass type coolant passages. Although the effects of the coriolis and buoyancy forces due to rotation on coolant-side heat transfer are generally not currently included in the design methods for blades, the influence of these forces could be large. Comparisons of non-rotating heat transfer data and extrapolations of available correlation for the average heat transfer coefficients with radial outflow of cooling air, showed that neglecting rotation at gas turbine engine conditions would result in variations in the heat transfer coefficient by as much as 45 percent. This, in effect, results in blade metal temperatures running as much as 100° F different from predicted values. This also may explain why rotating blade metal temperatures in engine tests are often higher than expected from results obtained in non-rotating cascade tests.

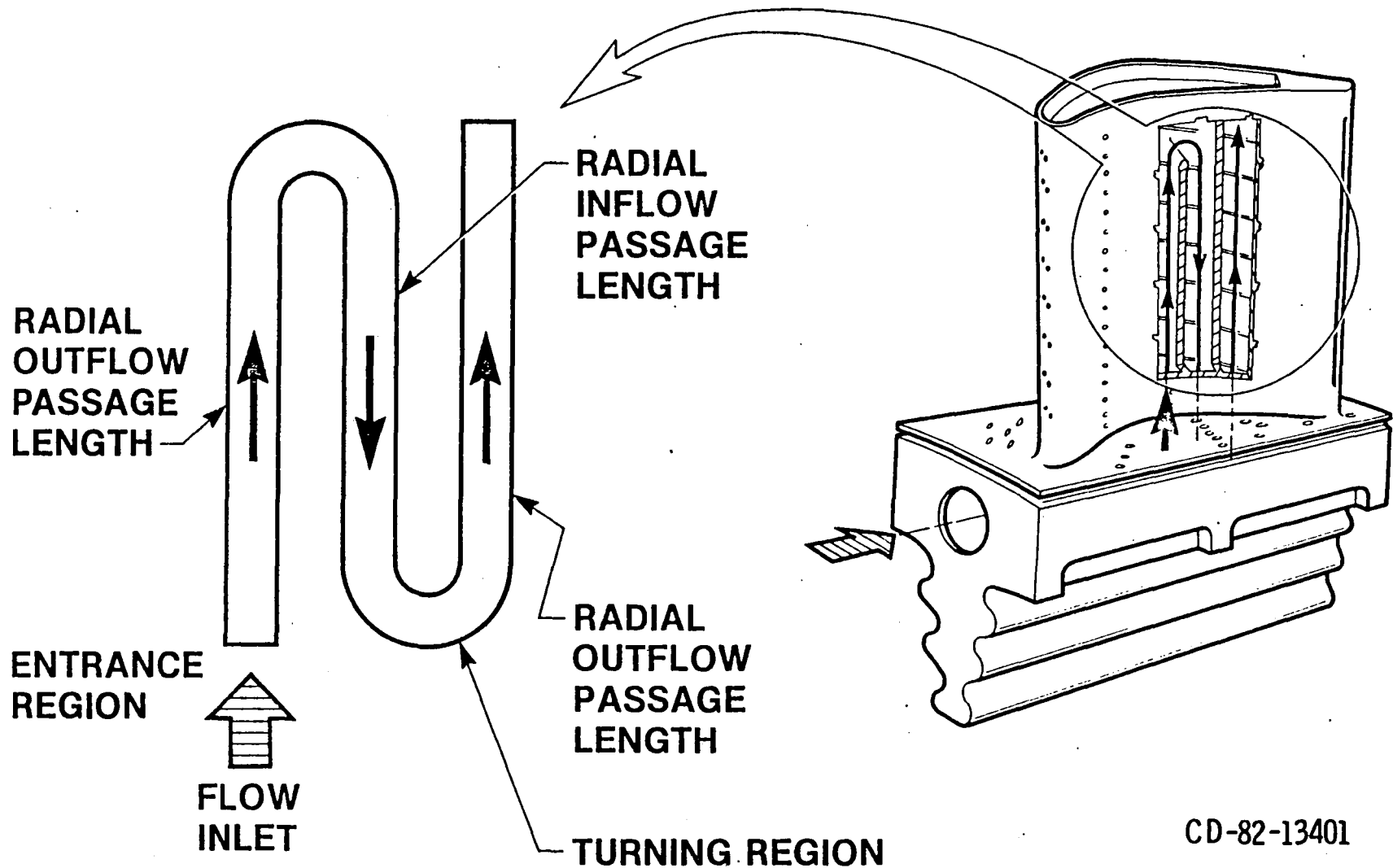
Although analytical computer code predictions have been obtained for such variations as coolant velocity and coolant temperature profiles within rotating coolant passages, and relatively good agreements have been obtained for predicted and measured heat transfer and friction factors, the results were for relatively low centrifugal buoyancy conditions. The high pressure and heat flux and the resultant large fluid density gradients combine with the high rotational speed of current and advanced gas turbine engines to require inclusion of the effects of coriolis and buoyancy forces in the predictive models. Generally beneficial effects on the average heat transfer are predicted from the effect of coriolis forces caused by rotation, but the buoyancy forces are expected to negate and augment the coriolis effect on heat transfer in coolant passages depending on the radial outflow and inflow of the

coolant flow respectively.

Although correlations have been obtained for the average heat transfer in rotating smooth passages with radial outflow of coolant for a large range of test conditions, further research is needed. Rotating experiments are needed to extend to local heat transfer along and around the passages and to the higher Rayleigh and Reynolds numbers that simulate geometry and the large fluid density gradients and buoyancy forces expected in advanced gas turbine engines. Rotating experiments are also needed dealing with the radial inflow of coolant, the interactive effects of entrance and turning regions, and the effect of wall boundary layer trips (turbulators).

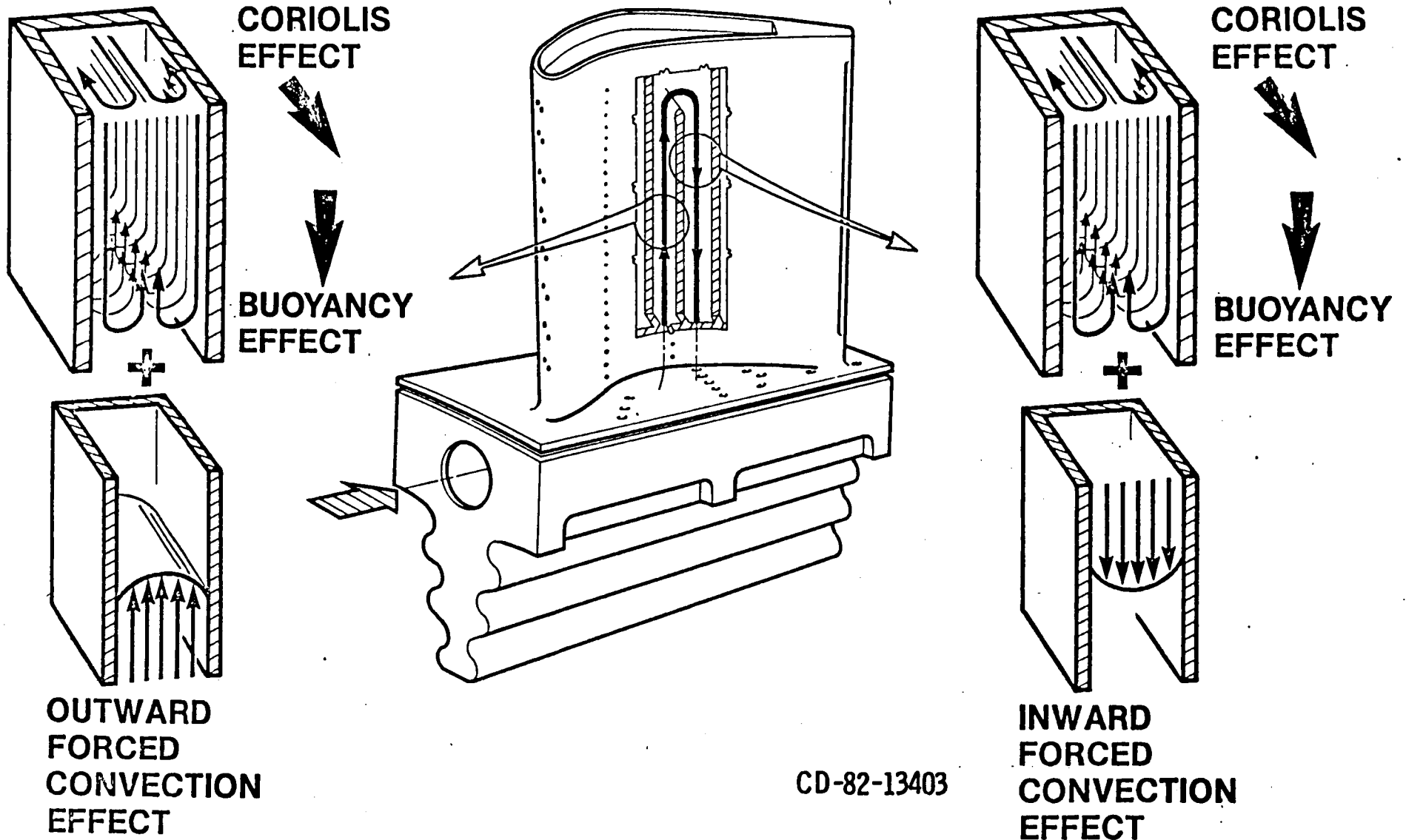
Correlations, analytical models, and computer codes will be developed and improved in order to accurately predict the heat transfer coefficients and local flow conditions within a multi-pass rotating turbine blade. These computer codes and correlations will be developed or improved to predict the local heat transfer coefficient at the entrance to the coolant passage, along the length of the passage, and in any flow recirculation regions of the passage, and the associated local coolant flow conditions. These requirements dictate initially a quasi three-dimensional viscous flow code with full consideration of rotation and buoyancy effects.

# SCHEMATIC OF COOLANT PASSAGE TEST UNIT



# COOLANT SIDE HEAT TRANSFER WITH ROTATION

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CD-82-13403

# SCHEMATIC OF PASSAGE ROTATIONS

⊗ RADIAL INFLOW

⊙ RADIAL OUTFLOW

