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3-D CFD ANALYSIS OF HYDROSTATIC BEARINGS

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ABSTRACT

The hydrostatic bearing promises life and speed characteristics currently unachievable with rolling element bearings alone. In order to achieve the speed and life requirements of the next generation of rocket engines, turbopump manufacturers are proposing hydrostatic bearing to be used in place of, or in series with, rolling element bearings.

The design of a hydrostatic bearing is dependent on accurate prediction of the pressure in the bearing. The stiffness and damping of the hydrostatic bearing is very sensitive to the bearing recess pressure ratio. In the conventional approach, usually ad hoc assumptions were made in determining the bearing pressure of this approach is inherently incorrect.

In the present paper, a more elaborate approach to obtain the bearing pressure is used. The bearing pressure and complete flow features of the bearing are directly computed by solving the complete 3-D Navier-Stokes equation .

The code used in the present calculation is a modified version of REACT3D code.

Several calculations has been performed for the hydrostatic bearing designed and tested at Texas A&M. Good agreement has been obtained between computed and test results. Detailed flow features in the bearing will be also described and discussed.

3-D CFD Analysis of Hydrostatic Bearings

by

Robert Hibbs, Jr., and Shyi-Jang Lin

Benefits of Hydrostatic Bearings in High Power Density Turbomachinery Led Rocketdyne to Pursue Aggressive IR&D Initiative to Improve Analysis Capability

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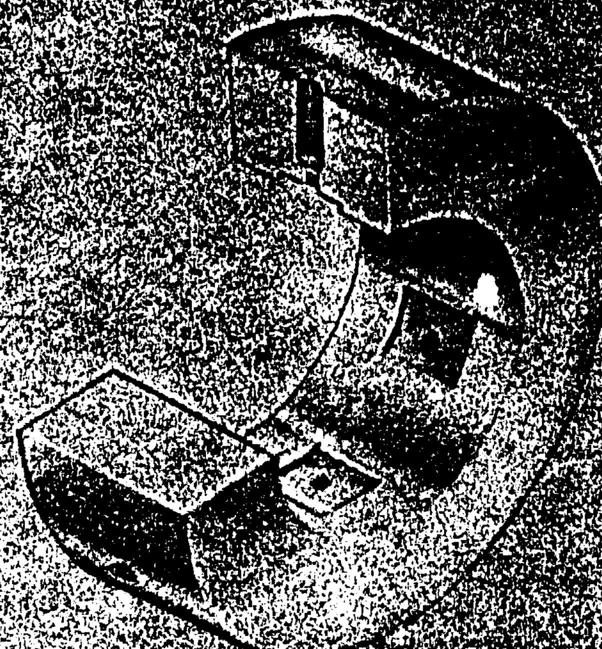
HYDROSTATIC BEARING
(CUTAWAY)



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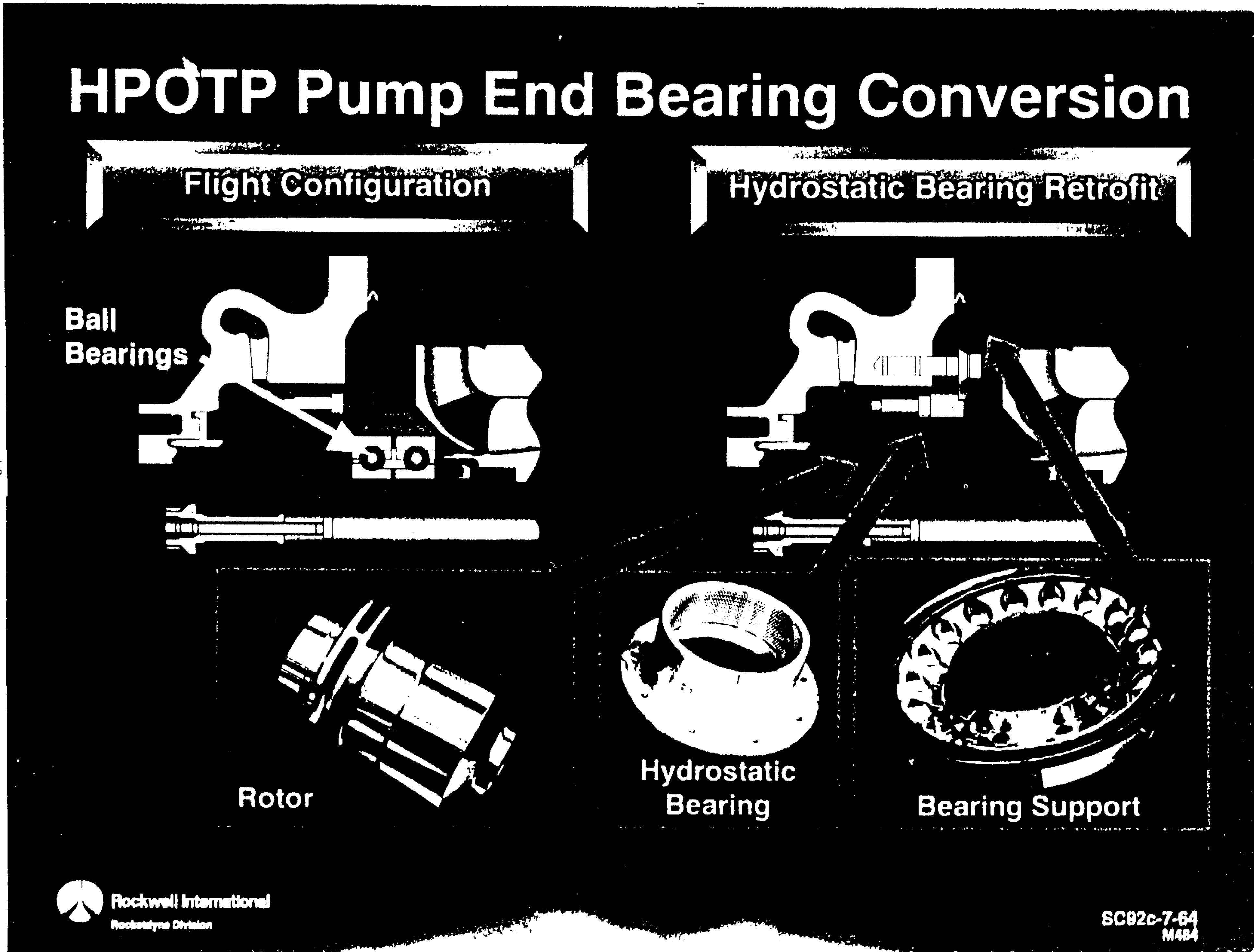
HPOTP Pump End Bearing Conversion
Flight Configuration
Hydrostatic Bearing Retrofit
Ball Bearings
Rotor
Hydrostatic Bearing
Bearing Support
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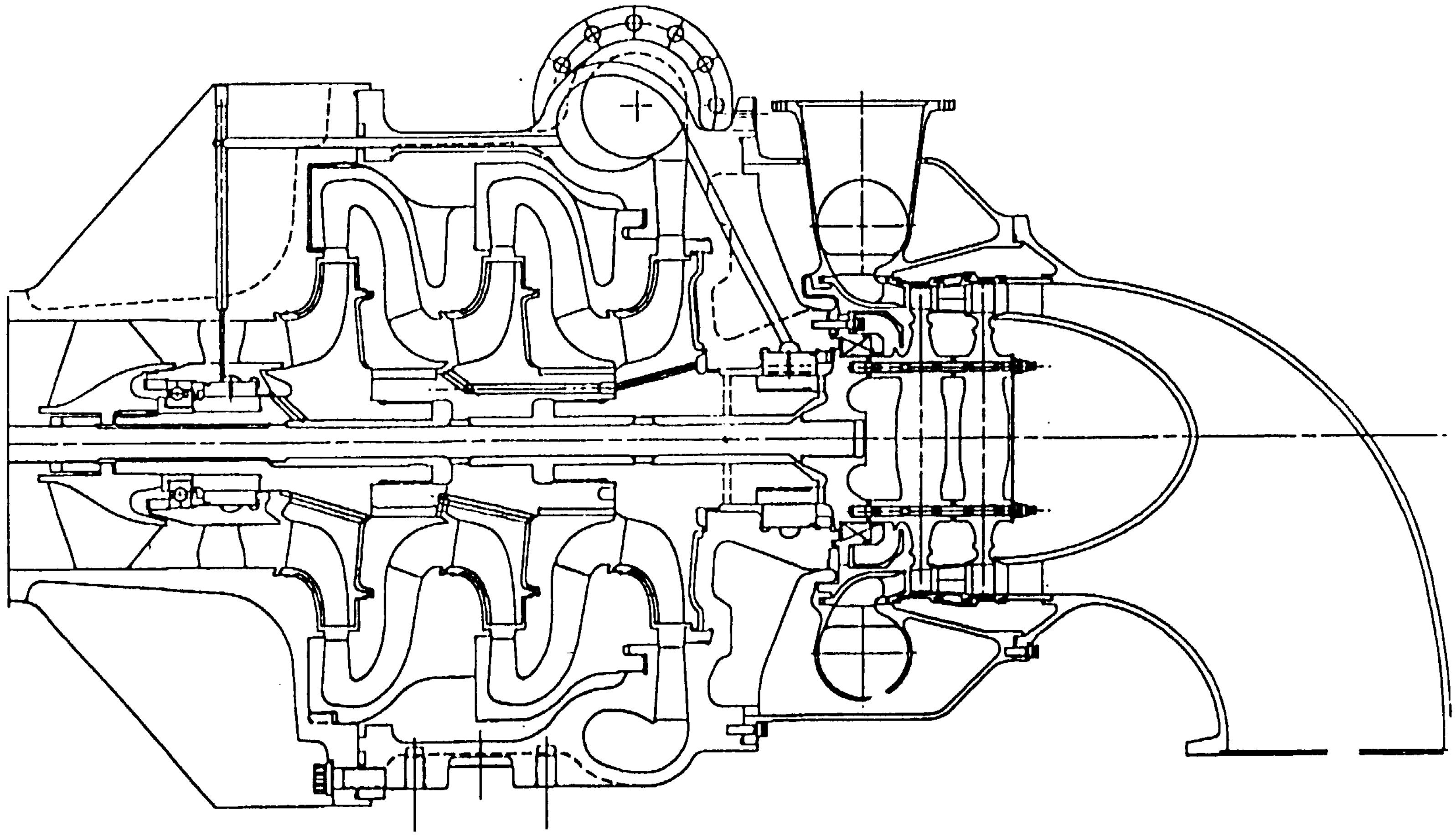
FUEL PUMP FOR NLS



Benefits:

- Low-Wear/ No Known Life LImit
- Reasonable Hardware Cost

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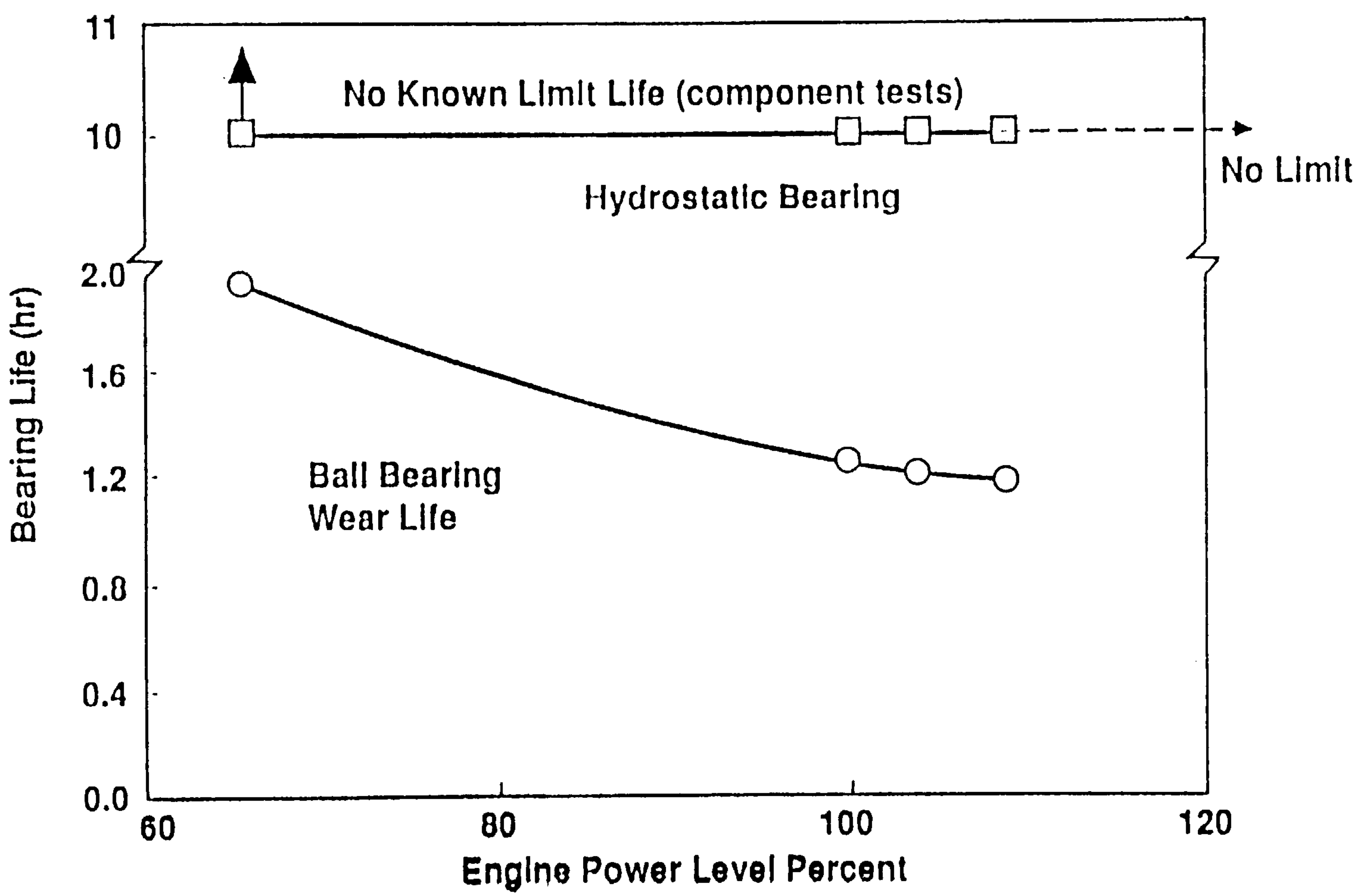
Significantly Improved Life & Power Level Margin With Hydrostatic Bearing



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Analysis Requirement:

- Improve Accuracy of Rotordynamic Model Input
  - Direct Stiffness
  - Cross-Coupled Stiffness
  - Direct Damping
  - Added Mass

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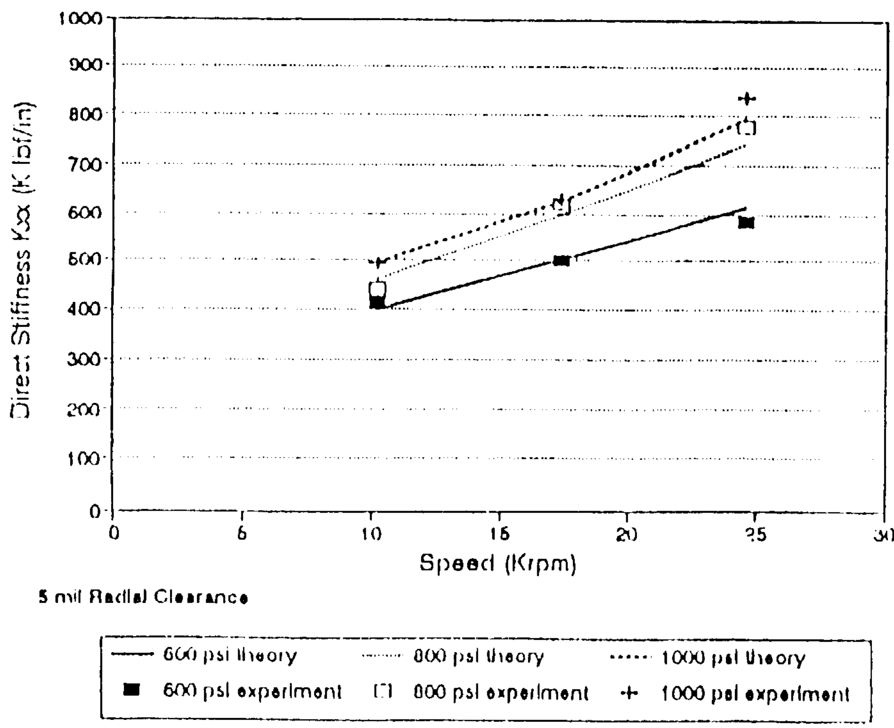
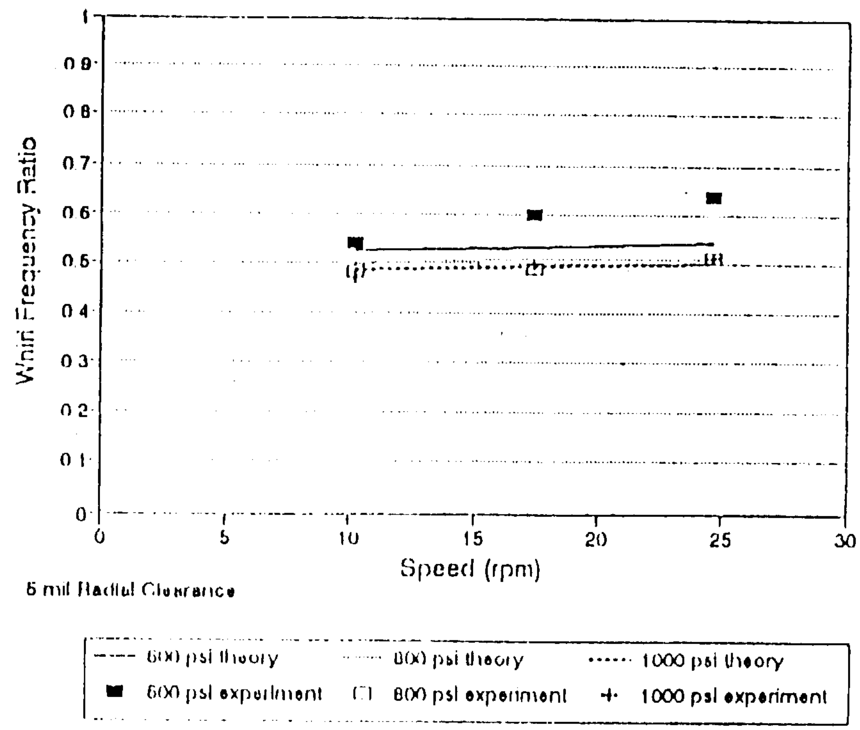
Analysis Method:

- Bulk-Flow Analysis Operational and Anchored
  - Film-averaged Navier Stokes Eqn Across Lands
  - Recess Pressure Constant / Including orifice
  - Loss Coefficient Used to Determine Pressure at Entrance to Bearing Land
- Currently Improving with Steady-State 3-D CFD
  - Anchor Loss Coefficients for Bulk Flow Model
- Full Bearing Perturbation Solution of 3D Steady-State Solution
- Steady Solution with Eccentric Shaft
- Unsteady Solution with Whirling Shaft

COMPARISON OF THEORY AND EXPERIMENT
TEXAS A&M HYDROSTATIC BEARING TESTING

	Difference		
	MIN	AVG	MAX
Direct Stiffness (K_{xx})	-5%	+7%	+20%
Cross-Coupled Stiffness (K_{xy})	-26%	+2%	+16%
Direct Damping (C_{xx})	-22%	-5%	+13%
$WFR = K_{xy} / \omega C_{xx}$ Whirl Frequency Ratio	-15%	+1%	+8%





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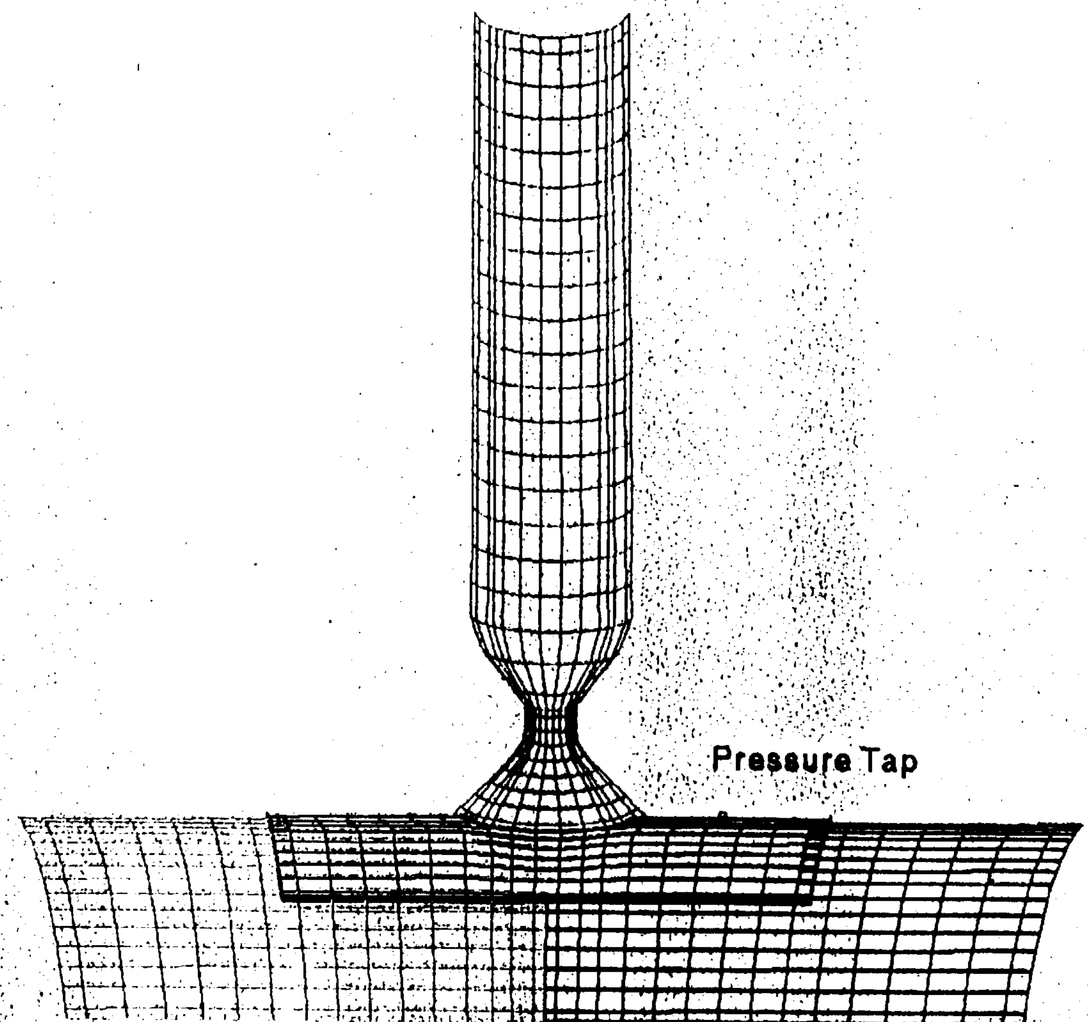
Grid Generation Challenges:

- Circular Orifice to Square Recess
- Circular Orifice Matching Recess Curvature
- Aspect Ratio in Bearing Land
- Solved Through Multi-Zone Approach
    - 5 Zones

Entrance	22X8X8
Orifice	10X8X8
Recess	6X20X20
Land-1	6X32X17
Land-2	6X32X17

- Total in Model - 10976

3D Multi-Zone Grid of H/S Bearing



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Methodology

- 3 D Steady-State Accurate Finite Volume Formulation in Generalized Coordinates
- Full Navier-Stokes (FNS) 1st and 2nd Order Upwind/Central Spatial Discretization
- Simple Based Velocity-Pressure Coupling
- k- ε Turbulence Modelling with Wall Function
- Multiple Zone Approach

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Boundary Conditions

- No-slip at stationary wall
- Specify velocities at the inlet
- Extrapolate the flow velocity variables from the interior point at the outlet
- No slip relative to the rotating shaft
- Periodic conditions between recesses
- Consistent formulation of interface Zonal conditions

Results:

- Within 5% of Recess Pressure Loss
- Qualitative Agreement of Flowfield
- Matches Assumptions of Bulk Flow Model

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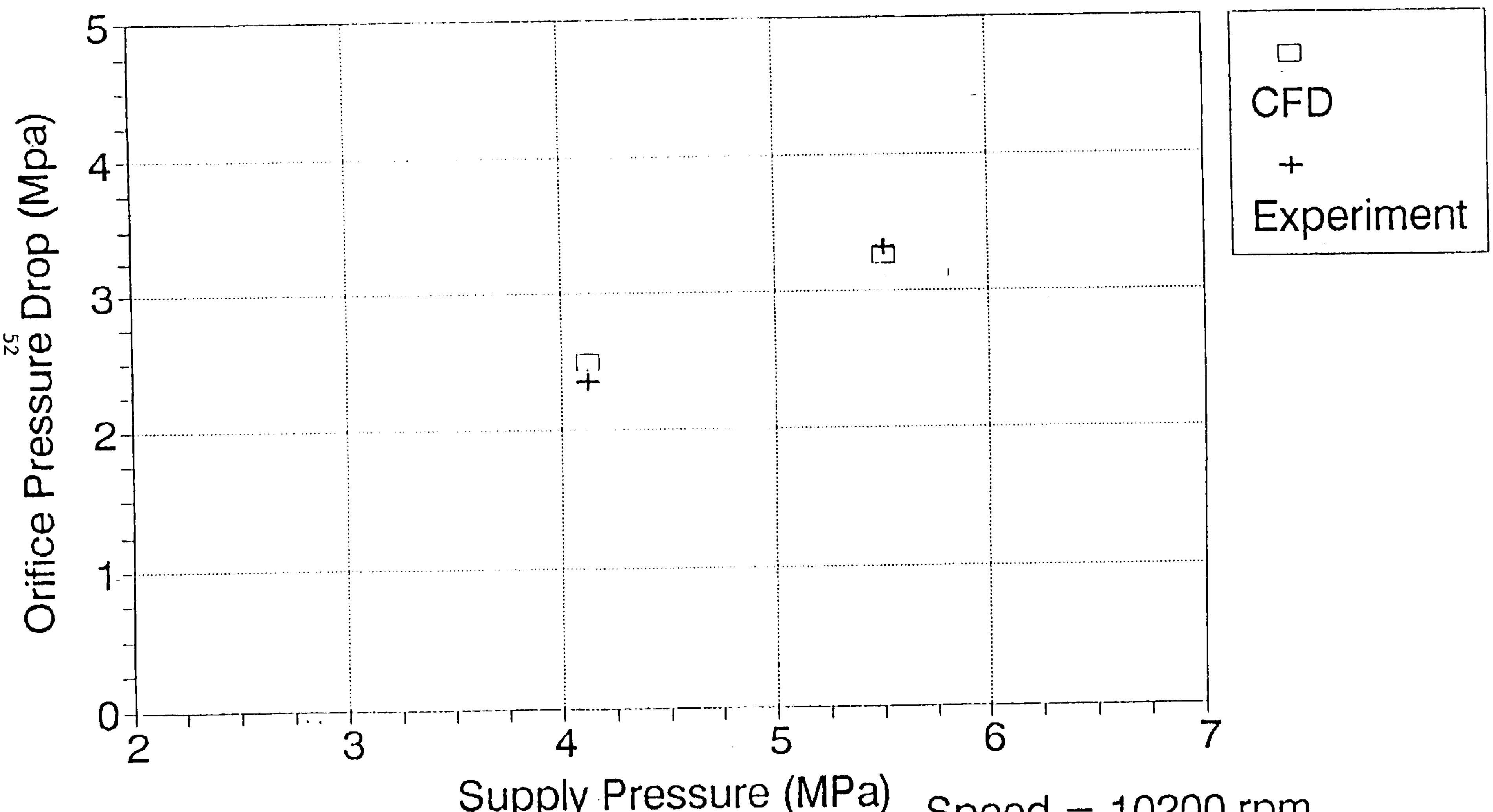
Code Development and Verification

TAMU Data Compared to CFD Solution



Speed = 10200 rpm
Clearance = 0.126 mm

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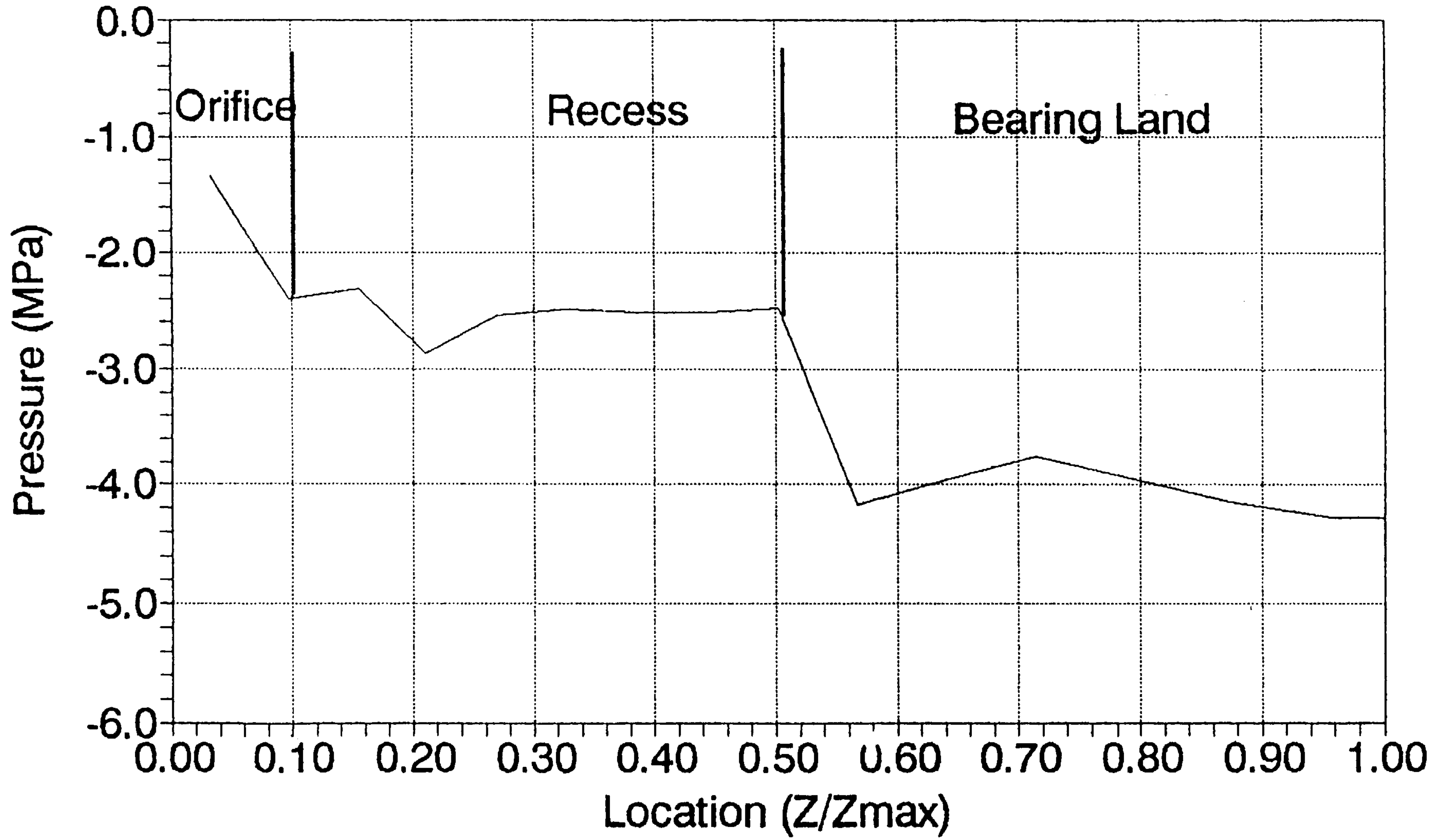
3-D CFD Pressure Solution

Axial Line Plot in Bearing Clearance



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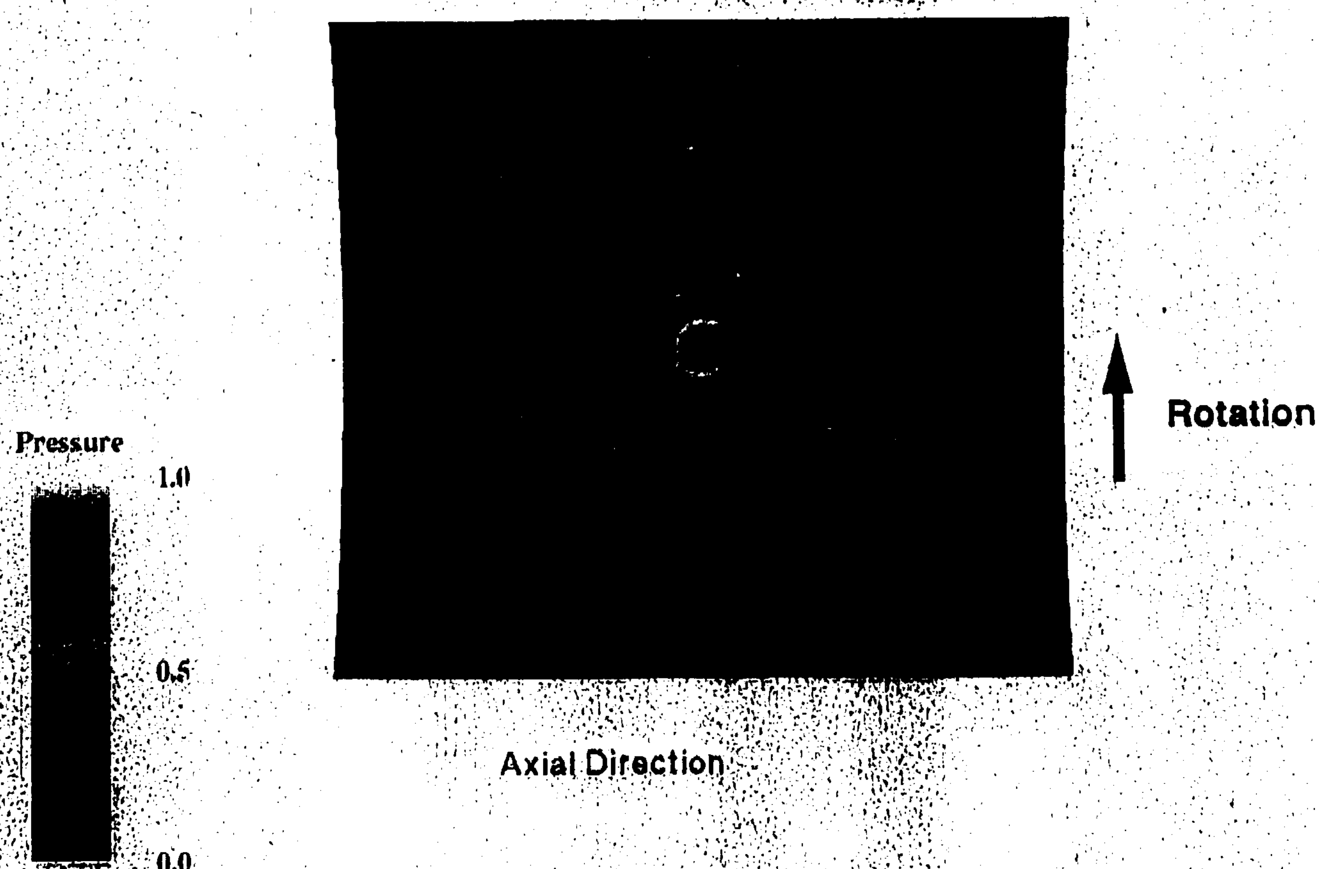
Pressure Contour at Clearance Radial Plane



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Conclusions:

- REACT3D Successfully Predicted Hydrostatic Bearing Solution on Actual Concentric Geometry
- 3-D CFD Solution Supports Main Assumptions of Bulk- Flow Model
  - Flow Variables Constant Across Bearing Clearance
  - Recess Pressure Constant
- Improvements to Bulk -Flow Solution will be Determined by Evaluation of Differences
  - Pressure Recovery at Entrance to Recess and Land

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