The industrial codes will consist of modules of 2-D and simplified 3-D or 1-D codes, intended for expeditious parametric studies, analysis and design of a wide variety of seals. Integration into a unified system is accomplished by the industrial KBS, which will also provide User Friendly interaction, contact sensitive and hypertext help, design guidance and an expandable database.

Major seal types include Cylindrical Seals and Face Seals, and within each type are a wide variety of configurations. For example, cylindrical seals include uniform, step, taper, hydrostatic, segmented, damping, labyrinth, and spiral-groove configurations. More advanced types include brush seals, electro-fluids seals and smart seals.

The types of analyses to be included with the industrial codes are interfacial performance (leakage, load, stiffness, friction losses, etc.), thermoelastic distortions, and dynamic response to rotor excursions.

The first three codes to be completed and which are presently being incorporated into the KBS are the compressible spiral-groove codes, SPIRALG, the incompressible cylindrical code, ICYL, and the compressible cylindrical code, GCYL.

The spiral-groove codes analyzes both shaft seals and face seals with finite eccentricity and misalignment. Four degrees of freedom are included for cylindrical seals, and three for face seals. The code predicts load, flow, power loss, and cross-coupled dynamic spring and damping coefficients, shaft displacements and minimum film thickness.

The ICYL (Incompressible Cylindrical Code) is a 2-D isoviscous code that includes roughness, multiple geometries (steps, pockets, tapers, preloaded axes, and hydrostatic), turbulence, cavitation, and inertia at inlets to the film. Included are eccentricity and misalignment and variable grid specifications. Specified pressure and periodic boundary conditions can be applied. It produces pressures, flows, load, righting moments, film thickness, power loss and cross-coupled dynamic spring and damping coefficients.

GCYL is a gas cylindrical code that can treat varying geometries (steps, tapers, hydrostatic, lobed, segmented). Shaft eccentricity, misalignment, specified boundary pressures or periodic boundary conditions can be applied. The program produces the clearance distribution, pressure distribution, leakage, load, moments, power loss and cross-coupled dynamic spring and damping coefficients.
Objectives:

- Compile and generate sets of verified 2D and simplified 3D or 1D codes
- Codes are intended for expeditious parametric studies, analysis and design of a wide variety of seals
- Integration is accomplished by the Industrial KBS.
  Additional functions of the KBS are:
  - User Friendly Interaction
  - Contact Sensitive and Hypertext Help
  - Design Guidance
  - Expandable Database

SEAL TYPES – COMPRESSIBLE OR INCOMPRESSIBLE

Bushing and Ring Seals

- Uniform
- Axial Step
- Axial Taper
- Hydrodynamic Step
- Hydrodynamic Taper
- Self-Energized Hydrostatic
- Segmented
- Damping Seals
- Spiral Groove
Circumferential Multilobe
(with or without ground)

Tapered in Flow Direction

Self-Energized — Hydrostatic
(Inherent Compensation Orifice Compensation Spot Orifices Recesses)

Circumferential Rayleigh Step

Rayleigh Step in Direction of Flow

SEGMENTED RING SEAL

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Material</th>
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<tbody>
<tr>
<td>1</td>
<td>Segmented Ring</td>
<td>Carbon</td>
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<tr>
<td>2</td>
<td>Rayleigh Step</td>
<td>Inconel X-750</td>
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<tr>
<td>3</td>
<td>Spring-Reset</td>
<td>Inconel X-750</td>
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<tr>
<td>4</td>
<td>Housing</td>
<td>Stainless Steel 17-4 PH</td>
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<tr>
<td>5</td>
<td>Cover</td>
<td>Stainless Steel 17-4 PH</td>
</tr>
<tr>
<td>6</td>
<td>Step Pin</td>
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<tr>
<td>7</td>
<td>Seal</td>
<td>Teflon</td>
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<tr>
<td>8</td>
<td>Sleeve</td>
<td>Inconel 718</td>
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<tr>
<td></td>
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<td>Hard Chromium Plated</td>
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</tbody>
</table>

ORIGINAL PAGE IS OF POOR QUALITY
DAMPING SEAL-LEAKAGE FLOW DAMPENS ROTOR MOTION; 
ROUGH STATOR HINDERS ROTOR WHIRL
SEAL TYPES - COMPRESSIBLE OR INCOMPRESSIBLE

Face Seals

- Contact Face Seals
- Radial Step
- Radial Taper
- Hydrodynamic Step
- Hydrodynamic Taper
- Hydrostatic
- Spiral Groove
- Multi-pad

Hydrostatic

Circumferential Rayleigh Step

Circumferential Tapered Land

Radial Rayleigh Step

Radial Tapered Land

GFACE Configurations
Direction of Rotation
Providing Pumping
Grooves Rotate

Land Width
Groove Width

Groove Angle = $\alpha$
Groove Depth = GD
Land Width/Groove Width = $\gamma$

- SPIRAL GROOVE PARAMETERS
CONTACT FACE SEAL WITH ROTATING SEAL RING

CONTACT FACE SEAL WITH NON-ROTATING SEAL RING

(Dimensions in mm Unless Otherwise Noted)
Brush Seals

Labyrinth Seals

- Straight
- Stepped
- Abradable
- Angled

Electro-Fluids Seals

Smart Seals

Effect of Bristle Overhang

Small overhang gives small axial deflection

Larger overhang gives larger axial deflection

Position of rotor CD

X Section A-A

DIAGRAM SHOWING TYPICAL BRUSH SEAL ARRANGEMENT
“C” Radial Clearance

Dimensions in inches unless otherwise specified

ORIGINAL INLET SEAL

OPTIMIZED STRAIGHT INLET SEAL
MAGNETIC FLUID SEAL

HIGH-SPEED POSITION OF FLUID (CENTRIFUGAL SEAL)

HEAT EXCHANGER
COOLING WATER

NONMAGNETIC MATERIAL

ZERO OR SLOW SPEED POSITION OF FLUID (MAGNETIC SEAL)

MAGNETIC MATERIAL, MAGNETIZED BY PERMANENT OR ELECTROMAGNET

HIGH-PRESSURE REGION

LOW-PRESSURE REGION

ROTATING COLLAR

FUNDAMENTAL SEAL CONFIGURATION

ANALYTICAL TRIAD

Optimize Geometry for Seal Performance

Interfacial Analysis

Dynamic Response

Determine if Dynamic Response is Acceptable

Thermoelectric Distortions

Determine if Distortions are Excessive
Code Deliverables

<table>
<thead>
<tr>
<th>Code Module</th>
<th>Approximate Delivery Date</th>
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<tbody>
<tr>
<td>GCYL (Gas Cylindrical)</td>
<td>02/01/91 ➟</td>
</tr>
<tr>
<td>ICYL (Incompressible Cylindrical)</td>
<td>03/01/91 ➟</td>
</tr>
<tr>
<td>SPIRAL (Gas Spiral Groove)</td>
<td>04/01/91 ➟</td>
</tr>
<tr>
<td>CFD Cylindrical Code</td>
<td>02/01/92 ⇒</td>
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<tr>
<td>IFACE (Incompressible Face)</td>
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<tr>
<td>GFACE (Gas Face)</td>
<td>03/01/92 ⇒</td>
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<tr>
<td>SPIRALI (Incompressible-Spiral Groove)</td>
<td>04/01/92 ⇒</td>
</tr>
<tr>
<td>FACEDY (Face-Dynamics)</td>
<td>02/01/93 ⇒</td>
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<tr>
<td>RINGDY (Ring-Dynamics)</td>
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<tr>
<td>LABYRINTH (Gas)</td>
<td>04/01/93 ⇒</td>
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<tr>
<td>Augmented CFD Cylindrical Module</td>
<td>02/01/94 ⇒</td>
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<tr>
<td>FACECON (Face Contact)</td>
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<tr>
<td>DISTORTION (Thermo Elastic Distortion)</td>
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<tr>
<td>Additional Codes</td>
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<tr>
<td>• Brush</td>
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<td>• Damping Seal</td>
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<tr>
<td>CFD Code, Face, Wave, Groove Module</td>
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<tr>
<td>Industrial KBS</td>
<td>04/01/96 ⇒</td>
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<tr>
<td>Scientific KBS</td>
<td>04/01/96 ⇒</td>
</tr>
<tr>
<td>CFD, Tip, Contact, Non-Continuous Module</td>
<td>09/01/96 ⇒</td>
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</tbody>
</table>
PLANNED ACTIVITY

- Code unification and completion
  - Unified Grid Generator
  - On-line Help

- Code documentation
  - Consistent with KBS usage

- Additional problems and checkout

- Annual report