INDUSTRIAL CODE DEVELOPMENT

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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
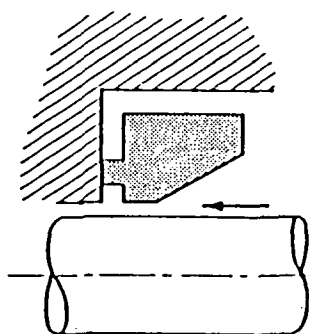
SEAL TYPES – COMPRESSIBLE OR INCOMPRESSIBLE

Bushing and Ring Seals

- Uniform

- Axial Step

- Axial Taper

- Hydrodynamic Step

- Hydrodynamic Taper

- Self-Energized Hydrostatic

- Segmented
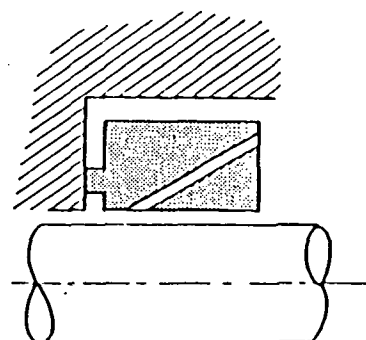
- Damping Seals

- Spiral Groove
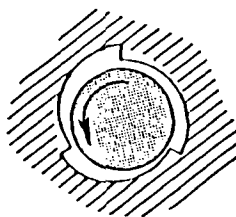
Circumferential Multilobe
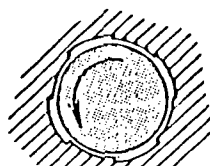
(with or without grooves)
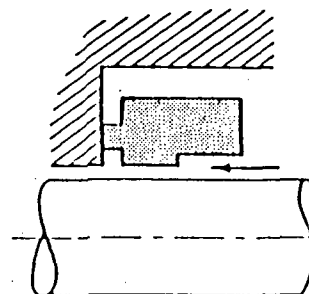
Tapered In Flow Direction
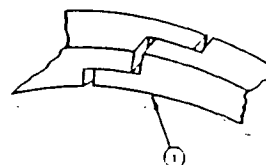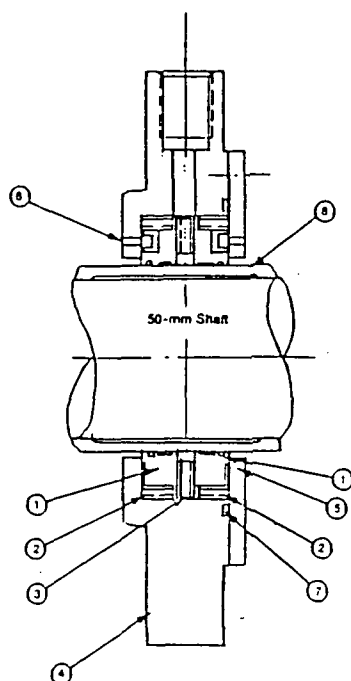
Self-Energized — Hydrostatic

(Inherent Compensation
Orifice Compensation
Spot Orifices
Recesses)

Circumferential Rayleigh Step

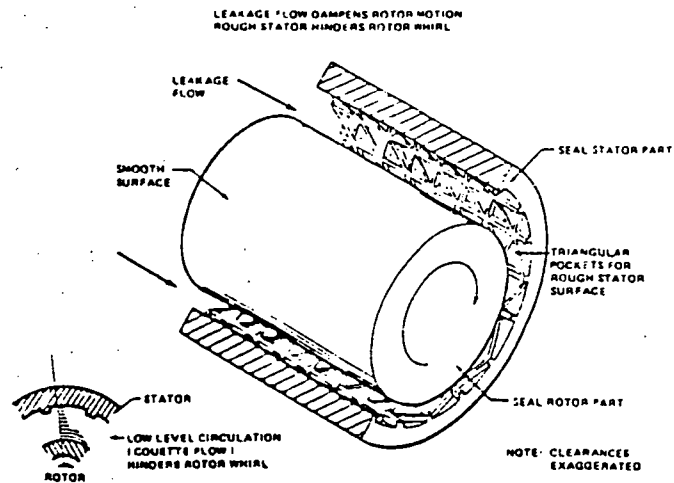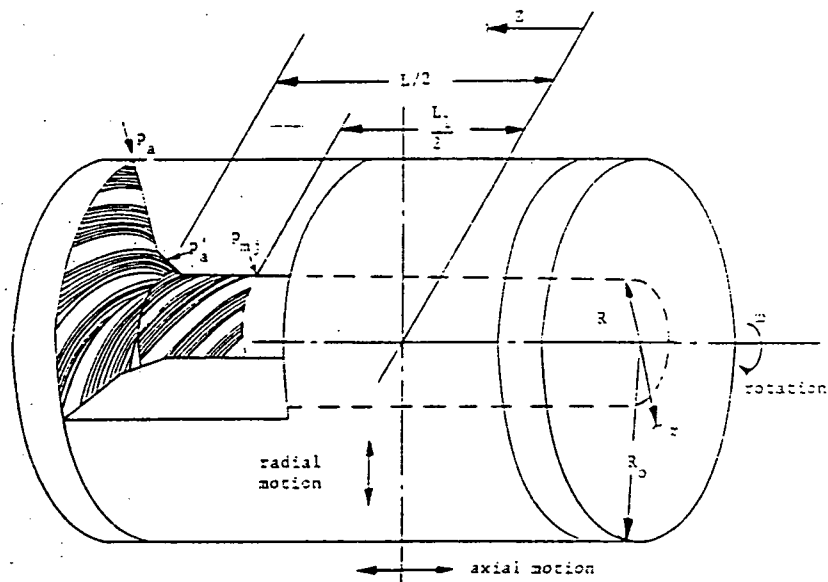**Rayleigh Step In Direction of Flow**

50-mm Shaft

Item	Description	Material
1	Segmented Ring Rayleigh Step	Carbon
2	Spring-Radial	Inconel X-750
3	Spring-Axial	Inconel X-750
4	Housing	Stainless Steel 17-4 PH
5	Cover	Stainless Steel 17-4 PH
6	Stop Pin	Stainless Steel 17-4 PH
7	Seal	Teflon
8	Sleeve	Inconel 718 Hard Chromium Plated

SEGMENTED RING SEAL

LEAKAGE FLOW DAMPENS ROTOR MOTION
ROUGH STATOR HINDERS ROTOR WHIRL

LEAKAGE FLOW

SMOOTH SURFACE

SEAL STATOR PART

TRIANGULAR POCKETS FOR ROUGH STATOR SURFACE

SEAL ROTOR PART

STATOR

LOW LEVEL CIRCULATION (COUETTE FLOW) HINDERS ROTOR WHIRL

ROTOR

NOTE: CLEARANCES EXAGGERATED

DAMPING SEAL-LEAKAGE FLOW DAMPENS ROTOR MOTION;

ROUGH STATOR HINDERS ROTOR WHIRL

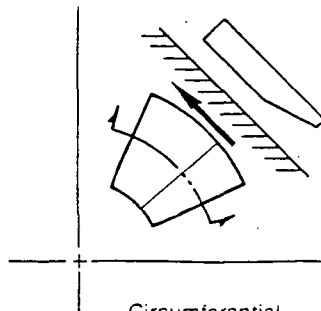**SPIRAL-GROOVE**

Face Seals

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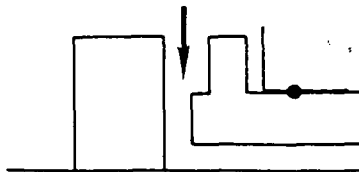- Hydrodynamic Taper
- Hydrostatic
- Spiral Groove
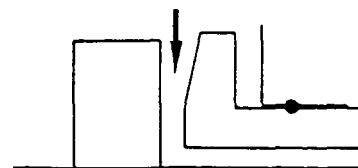- Multi-pad
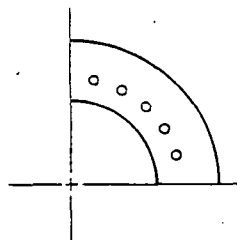
Hydrostatic
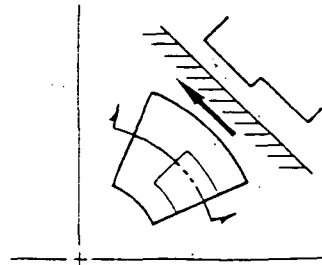
Circumferential Rayleigh Step

Circumferential Tapered Land

Radial Rayleigh Step

Radial Tapered Land

GFACE Configurations

Direction of Rotation
Providing Pumping →
Grooves Rotate

Land
Width

Groove
Width

R_m

R_i

R_o

Groove
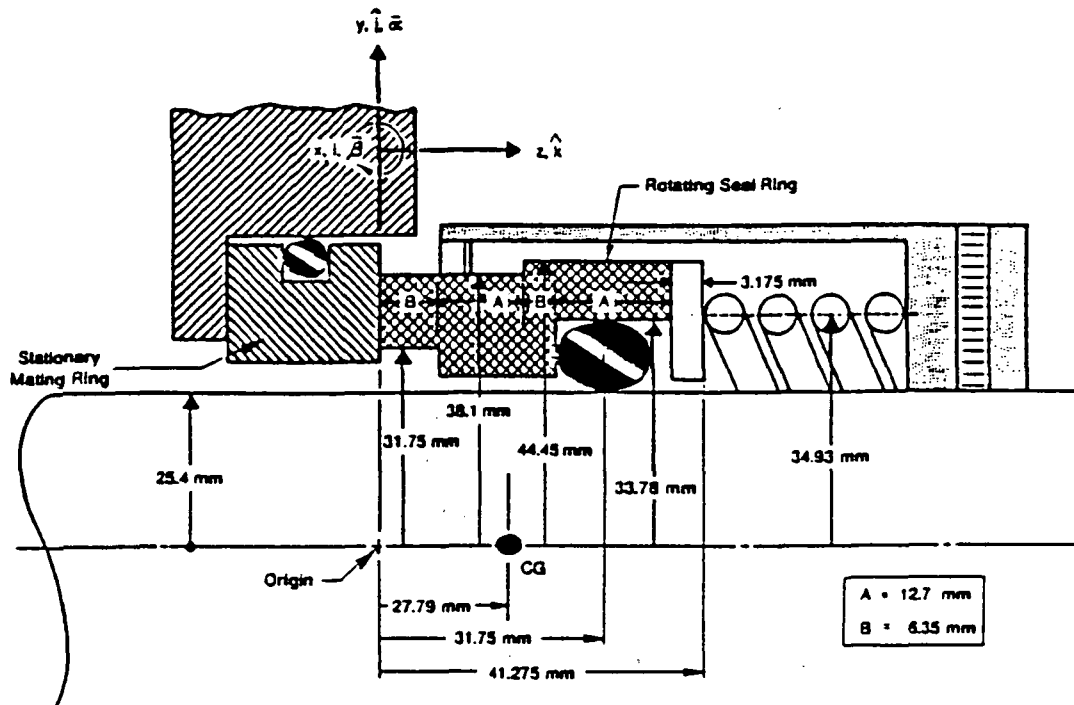Angle
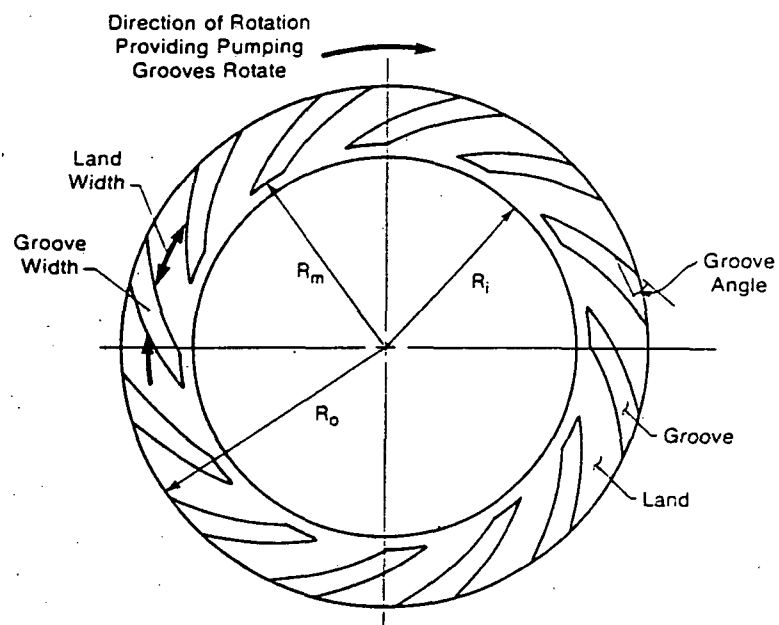
Groove

Land

Groove Angle = α
Groove Depth = GD
Land Width/Groove Width = γ

SPIRAL GROOVE PARAMETERS

y. L̂ ᾱ

z L̂ β̄

z k̂

Rotating Seal Ring

Stationary
Mating Ring

3.175 mm

38.1 mm

31.75 mm

44.45 mm

34.93 mm

25.4 mm

33.78 mm

Origin

CG

27.79 mm

31.75 mm

41.275 mm

A = 12.7 mm
B = 6.35 mm

831853-1

CONTACT FACE SEAL WITH ROTATING SEAL RING

6.35 mm

12.7 mm

12.7 mm

Rotating
Mating Ring

44.45 mm

41.275 mm

38.1 mm

Nonrotating Seal Ring

33.782 mm

y. L̂ ᾱ

25.4 mm

31.75 mm

z. k

z L̂ β̄

Origin

CG

Z_{cg}

19.06 mm

25.4 mm
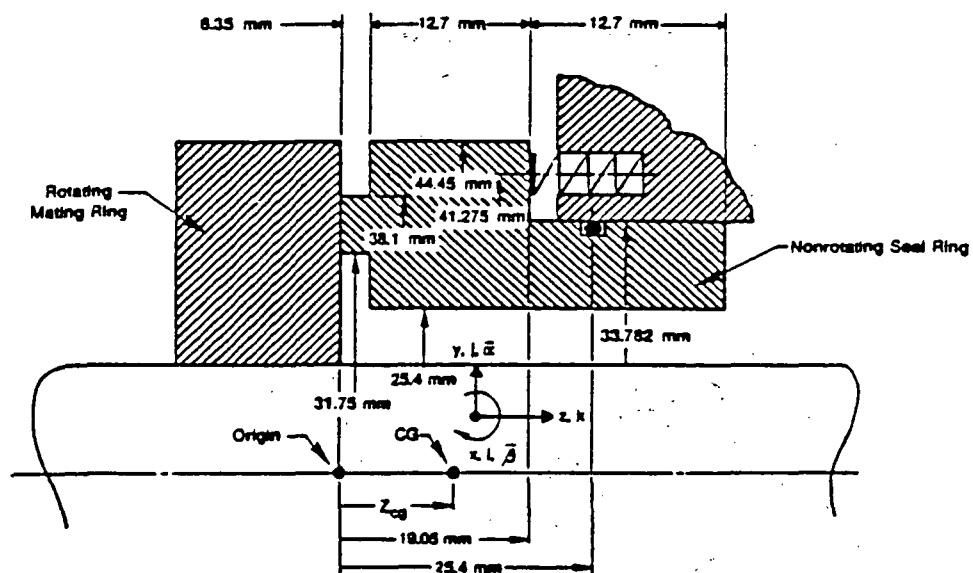
831834-1

CONTACT FACE SEAL WITH NON-ROTATING SEAL RING

(Dimensions in mm Unless Otherwise Noted)

21

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
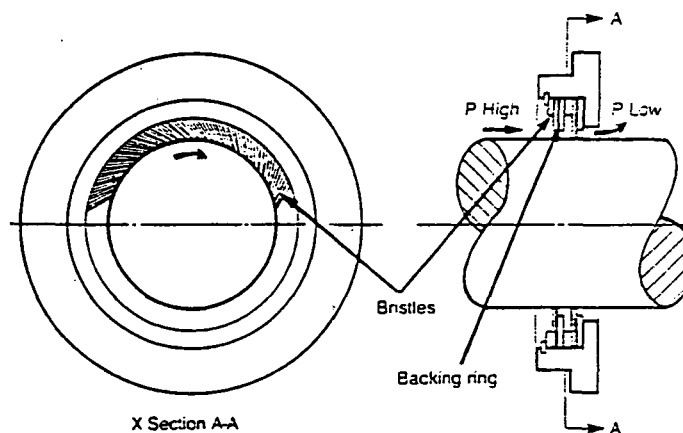
Position of rotor OD

P High   P Low

Bristles

Backing ring

X Section A-A
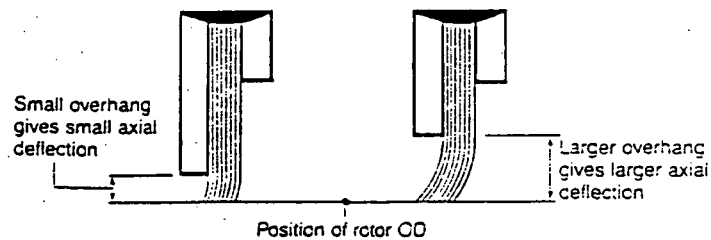
DIAGRAM SHOWING TYPICAL BRUSH SEAL ARRANGEMENT

0.312

20°

0.1875

"C" Radial
Clearance

φ 19

0.025

1.25

Dimensions in inches
unless otherwise specified
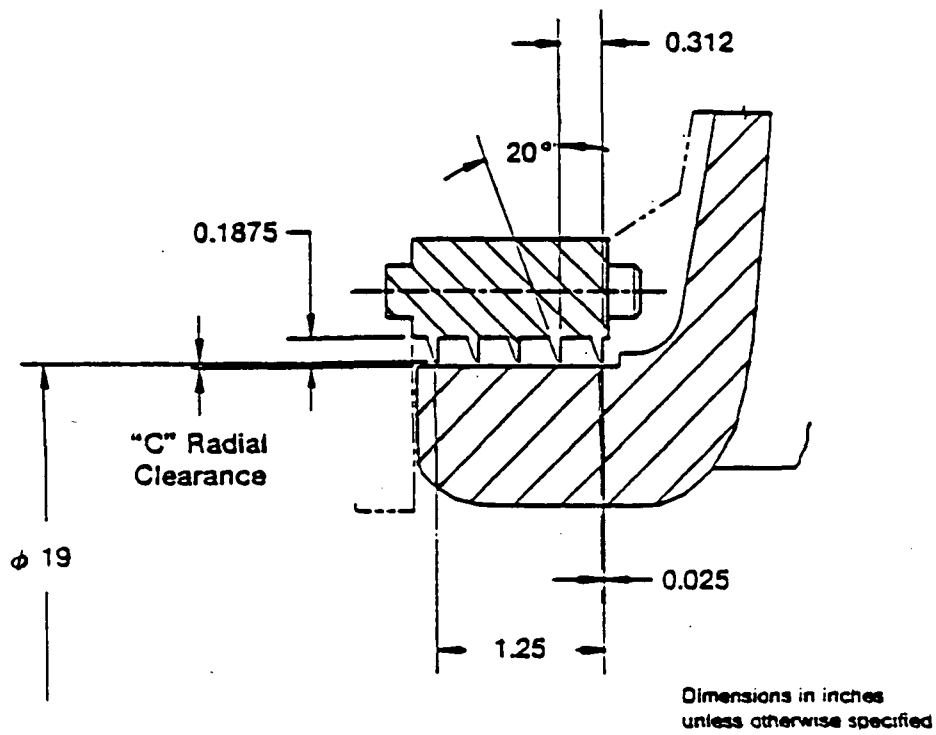
881815

ORIGINAL INLET SEAL

1.62

1.5

20°

0.16

"C" Radial
Clearance

60°

φ 19

0.005

0.16

Dimensions in inches
unless otherwise specified
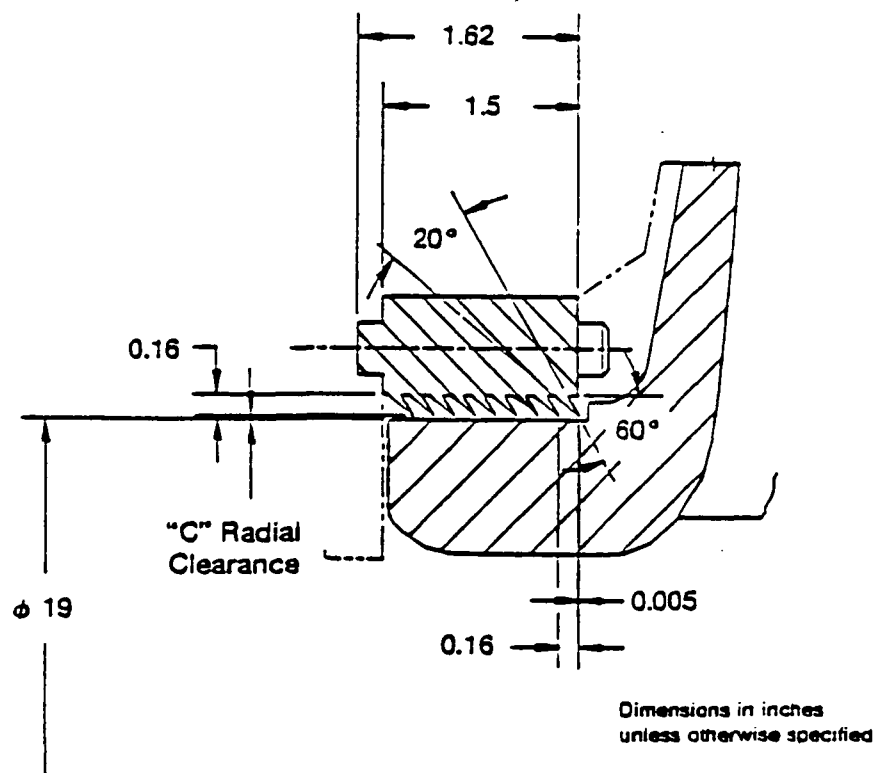
881816

OPTIMIZED STRAIGHT INLET SEAL

23

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

P_H HIGH-PRESSURE
REGION

P_L ~LOW-PRESSURE
REGION

ω

ROTATING COLLAR
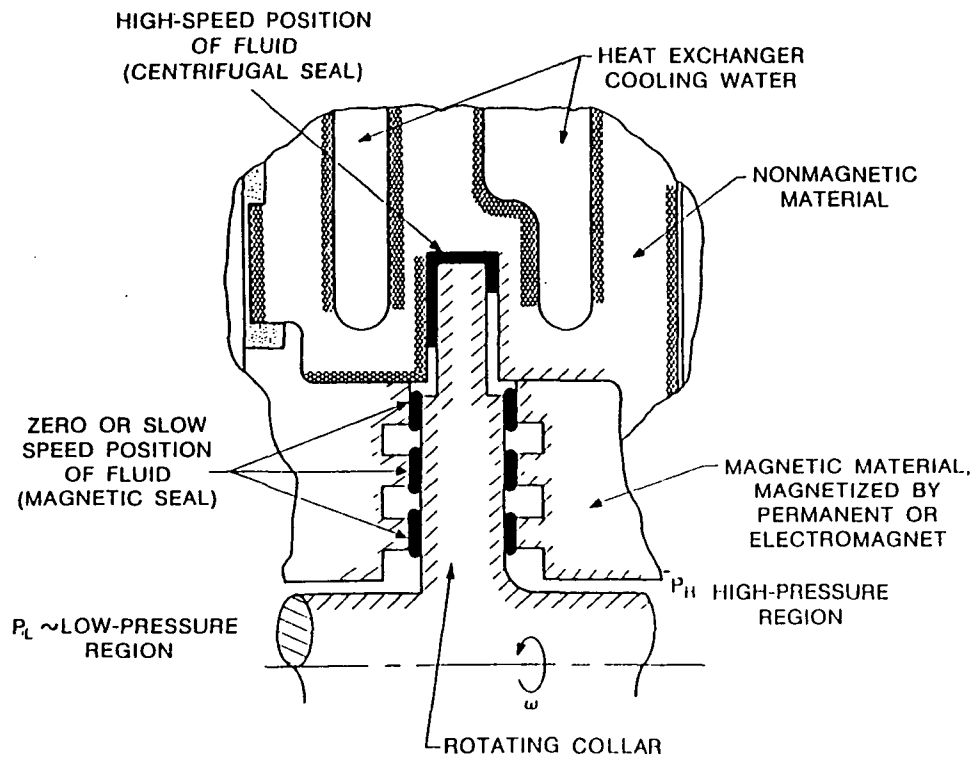
FUNDAMENTAL SEAL CONFIGURATION

Interfacial
Analysis

Optimize Geometry
for Seal Performance

Dynamic
Response

Thermoelastic
Distortions

Determine if Dynamic
Response is Acceptable

Determine if Distortions
are Excessive
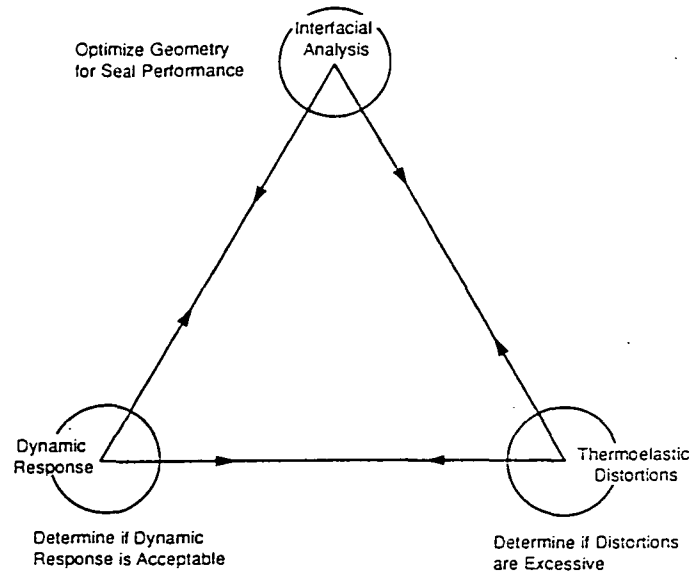
ANALYTICAL TRIAD
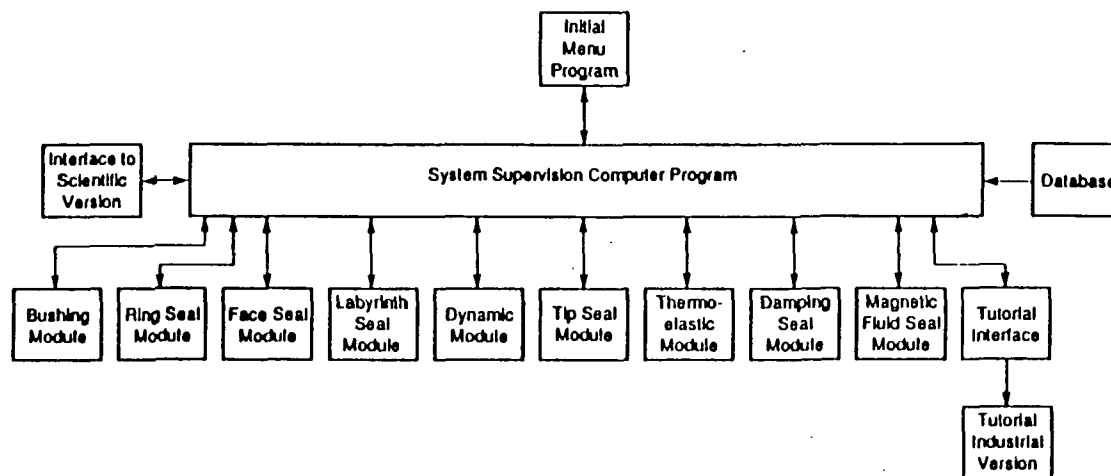
Code Deliverables

Code Module	Approximate Delivery Date
GCYL (Gas Cylindrical)	02/01/91 ←
ICYL (Incompressible Cylindrical)	03/01/91 ←
SPIRALG (Gas Spiral Groove)	04/01/91 ←
CFD Cylindrical Code	02/01/92
IFACE (Incompressible Face)	02/01/92
GFACE (Gas Face)	03/01/92
SPIRALI (Incompressible-Spiral Groove)	04/01/92
FACEDY (Face-Dynamics)	02/01/93
RINGDY (Ring-Dynamics)	03/01/93
LABYRINTH (Gas)	04/01/93
Augmented CFD Cylindrical Module	02/01/94
FACECON (Face Contact)	02/01/94
DISTORTION (Thermo Elastic Distortion)	04/01/94
Additional Codes	04/01/95
• Brush	
• Damping Seal	
CFD Code, Face, Wave, Groove Module	09/01/95
Industrial KBS	04/01/96 ←
Scientific KBS	04/01/96
CFD, Tip, Contact, Non-Continuous Module	09/01/96

PLANNED ACTIVITY

- Code unification and completion

  - Unified Grid Generator

  - On-line Help

- Code documentation

  - Consistent with KBS usage

- *Additional problems and checkout*

- Annual report