Navy GTE Seal Development Activity

by

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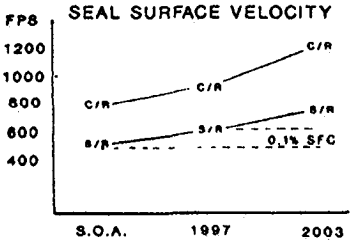
Under the auspices of the Integrated High Performance Turbine Engine Technology Initiative, the Naval Air Warfare Center conducts advanced development programs for demonstration in the next generation of air-breathing propulsion systems. Among the target technologies are gas path and lube oil seals. Two development efforts currently being managed by NAWCAD are the High Performance Compressor Discharge Film-Riding Face Seal and the Subsonic Core High Speed Air/Oil Seal.

The High Performance Compressor Discharge Film-Riding Face Seal Program aims at reducing parasitic leakage through application of a film-riding face seal concept to the compressor discharge location of a Phase II IHPTET engine. An order-of-magnitude leakage reduction relative to current labyrinth seal configurations is expected. Performance goals for these seals are (i) 1200 F air temperature, (ii) 800 feet-per-second surface velocity, and (iii) 600 PSI differential pressure. The two designs chosen for fabrication and rig test are a spiral groove and a Raleigh step seal. Rig testing is currently underway.

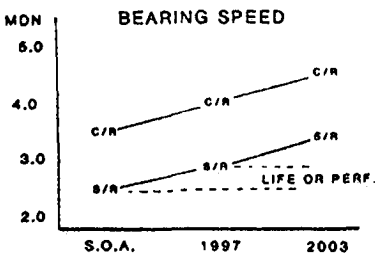
The Subsonic Core High Speed Air/Oil Seal Program is developing shaft-to-ground seals for next-generation propulsion systems that will minimize leakage and provide full life. Significantly higher rotor speeds and temperatures will be experienced. Technologies being exploited include, hydrodynamic lift assist features, ultra light weight designs, and improved cooling schemes. Parametric testing has been completed, a final seal design is entering the endurance test phase.

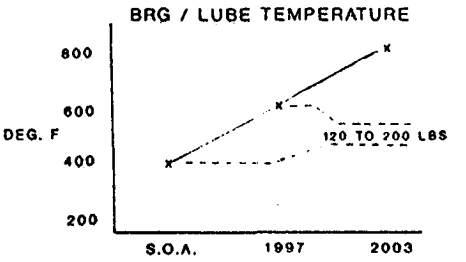
MECHANICAL SYSTEMS TECHNOLOGY
S.O.A. vs FUTURE REQUIREMENTS



SPEED AND TEMPERATURE TRENDS HAVE AN ADVERSE EFFECT ON MECHANICAL SYSTEMS:

- STRESS CYCLES ACCUMULATE FASTER, LIFE IN HOURS GOES DOWN.
- INTERFACIAL HEAT GENERATION GOES UP WITH VELOCITY.
- MATERIALS ALLOWABLES DROP WITH INCREASING TEMPERATURE.
- REQUIRED WEIGHT REDUCTIONS MAGNIFY THE ENVIRONMENTAL CHALLENGE.





MECHANICAL SYSTEMS PROJECT

CHALLENGE:

- SIGNIFICANTLY EXPAND COMPONENT OPERABILITY
  - SPEED, TEMPERATURE, LOAD
- SIGNIFICANT COMPONENT/SYSTEM WEIGHT REDUCTIONS
- REACT TO CURRENT DESIGN PRACTICE DEFICIENCIES

MECHANICAL SYSTEMS PROJECT
(WR22-P64)

TRENTON, NEW JERSEY

TASK 1: RADIAL AND AXIAL BEARINGS

TASK 2: LUBE OIL SEALS

TASK 3: STATIC AND DYNAMIC GAS PATH SEALS

MECHANICAL SYSTEMS PROJECT
TASK 1: AXIAL AND RADIAL BEARINGS

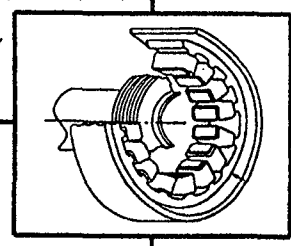
TRENTON, NEW JERSEY

FLEET ISSUES ADDRESSED:

- INCREASED ENDURANCE FOR EXTENDED COVERAGE FOR ASW/ASUW/AEW/EW/C3/DRUG MISSIONS
- INCREASED STANDOFF RANGE FOR POWER PROJECTION ASHORE
- HIGH PERFORMANCE ENGINES FOR EMERGING *SYSTEM REQUIREMENTS (AX, NATF, ASTOVL, SSF)*
- IMPROVED LIFE CYCLE COST THROUGH IMPROVED RELIABILITY
- IMPROVED A/C AVAILABILITY

TECHNOLOGIES:

- MAGNETIC BEARINGS
- THRUST COMPENSATION
- RADIAL LOAD COMPENSATION
- INNOVATIVE DESIGN
- IMPROVED MATERIALS
- IMPROVED DAMPERS



IHPTET/S&T RELIANCE JDL GOALS:

	PH I	PH 2	PH 3
TEMPERATURE (F)	400	600	800
BEARING SPEED (MDN)	2.5 3.7	3.0 4.2	3.5 4.5
WEIGHT	- 5 %	- 10 %	- 20 %

IHPTET/S&T RELIANCE JDL SYSTEM PAYOFFS:

	PH I	PH II	PH III
TIME ON STATION	+1.8%	+3.0%	+ 6 %
RANGE	+ 2 %	+ 4 %	+ 7 %
PAYLOAD	+ 18 %	+ 36 %	+ 50 %
FN / WT	+5.2%	+11.1%	+25.%

MECHANICAL SYSTEMS PROJECT
TASK 2: LUBE OIL SEALS

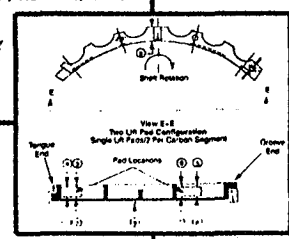
TRENTON, NEW JERSEY

FLEET ISSUES ADDRESSED:

- INCREASED ENDURANCE FOR EXTENDED COVERAGE FOR ASW/ASUW/AEW/EW/C3/DRUG MISSIONS
- INCREASED STANDOFF RANGE FOR POWER PROJECTION ASHORE
- HIGH PERFORMANCE ENGINES FOR EMERGING SYSTEM REQUIREMENTS (AX, NATF, ASTOVL, SSF)
- IMPROVED LIFE CYCLE COST THROUGH IMPROVED RELIABILITY
- IMPROVED A/C AVAILABILITY

TECHNOLOGIES:

- HYDRODYNAMIC LIFT ASSIST
- EXTREME LIGHTWEIGHT DESIGNS
- IMPROVED CARBON MATERIALS
- INNOVATIVE COOLING SCHEMES



IHPTET/S&T RELIANCE JDL GOALS:

		PH I	PH 2	PH 3
TEMPERATURE (F)		400	600	800
SEAL SPEED (FPS)	S/R:	500	600	750
	C/R:	900	1100	1300
WEIGHT		- 5 %	- 10 %	- 20 %

IHPTET/S&T RELIANCE JDL SYSTEM PAYOFFS:

	PH I	PH II	PH III
TIME ON STATION	+1.8%	+3.0%	+ 6 %
RANGE	+ 2 %	+ 4 %	+ 7 %
PAYLOAD	+ 18 %	+ 35 %	+ 60 %
FN / WT	+6.2%	+11.1%	+25.%

MECHANICAL SYSTEMS PROJECT
LUBE OIL SEALS

TRENTON, NEW JERSEY

SUBSONIC CORE HIGH SPEED AIR/OIL SEAL

CONTRACTOR: PRATT & WHITNEY

COST: $ 430 K

OBJECTIVE: DEVELOP SHAFT-TO-GROUND SUMP SEAL SYSTEMS FOR IHPTET PHASE II CONDITIONS THAT MINIMIZE LEAKAGE, GIVE FULL LIFE.

GOALS:

- PHASE II CONDITIONS:
  - 600 FPS
  - 60 PSID
  - FULL LIFE
  - 750 F AIR
  - 400 F OIL

MECHANICAL SYSTEMS PROJECT
LUBE OIL SEALS

TRENTON, NEW JERSEY

APPROACH:
- ANALYTICALLY ASSESS MULTIPLE SEALS
- DETAIL DESIGN AND FABRICATE THE TWO BEST CANDIDATE SEALS
- 25 HRS OPERABILITY EACH, REVISE
- ENDURANCE TESTING

TECHNOLOGIES:
- HYDRODYNAMIC LIFT ASSIST (STEIN)
- ULTRA-LIGHTWEIGHT DESIGN (REXNORD)
- IMPROVED PACKAGING / COOLING

ADVANCEMENT BEYOND SOA:
- ORDER OF MAGNITUDE LEAKAGE REDUCTION RELATIVE TO LAB SEALS (.1% SFC PER)
- 30% SPEED CAPABILITY INCREASE

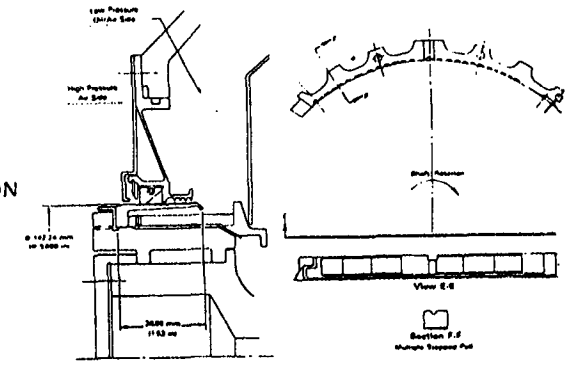
MECHANICAL SYSTEMS PROJECT

TRENTON, NEW JERSEY

STEIN HYDRODYNAMIC CIRCUMFERENTIAL NON-CONTACTING SEGMENTED SEAL

PROS:
- EXTENSION OF SUCCESSFUL SEGMENTED RING SEAL
- LOW LEAKAGE
- WEAR TO 6 MILS O.K.
- LIGHTWEIGHT
- WINDBACK ALLOWS MINIMUM LEAKAGE AND CONTAMINATION

CONS:
- MINIMAL EXPERIENCE WITH HYDRODYNAMIC LIFT GEOM. IN CARBON BORE.
- THERMAL CONEING AND MISALIGNMENT CONCERNS



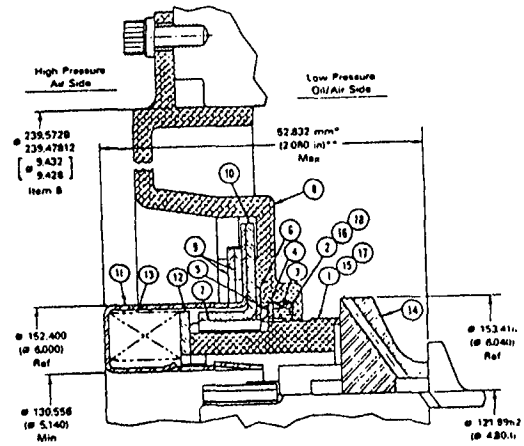
REXNORD CARTRIDGE-TYPE CONTACTING FACE SEAL

PROS:

- VERY LIGHTWEIGHT LOW DRAG DESIGN IMPROVES SPEED CAPABILITY.
- TOLERANT TO CONEING AND MISALIGNMENT.
- LOW TO MOD. LEAKAGE
- LOW OPERATING LOADS IMPROVE LIFE

CONS:

- NUMEROUS PARTS
- NARROW CARBON NOSE PRESENTS HANDLING DAMAGE RISK
- POSSIBLE LEAKAGE AT VERY LOW DELTA P's



MECHANICAL SYSTEMS PROJECT

LUBE OIL SEALS

STATUS:

* PHASE I OPERABILITY EVAL COMPLETE
  - MIXED RESULTS

* STEIN HYDRODYNAMIC CIRCUMFERENTIAL SEAL:
  * STATIC CAL DONE, VERY LOW LEAKAGE
  * RAN SUCCESSFULLY TO 600 FPS, 60 PSID !
  * LEAKGE CONSISTENTLY LOW, THEN -
    * BROKE EXTENSION SPRING - EASY FIX IN HAND

* REXNORD CARTIDGE-TYPE FACE SEAL:
  * STATIC CAL COMPLETED (INITIAL SEC. SEAL PROB)
  * VERY SUCCESSFUL THROUGH TWO DYNAMIC TESTS TO 600 FPS, 60 PSID !
    ** LEAKAGE TOOK OFF, SEAL FAILED
      * INVESTIGATION IN PROGRESS.

SUMMARY:

* MINOR REVISIONS TO STEIN SEAL, HIGH CONFIDENCE FOR ENDURANCE PHASE
* ASSESSMET OF REXNORD SEAL IN PROGRESS, ENDURANCE PROSPECTS TBD
* HAVE SHOWN STABLE LOW LEAKAGE OPERATION AT AGGRESSIVE GOAL CONDITIONS FOR BOTH.

MECHANICAL SYSTEMS PROJECT
TASK 3: STATIC & DYNAMIC GAS PATH SEALS

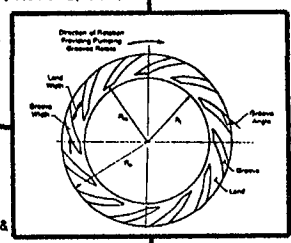
TRENTON, NEW JERSEY

FLEET ISSUES ADDRESSED:

- INCREASED ENDURANCE FOR EXTENDED COVERAGE FOR ASW/ASUW/AEW/EW/C3/DRUG MISSIONS
- INCREASED STANDOFF RANGE FOR POWER PROJECTION ASHORE
- HIGH PERFORMANCE ENGINES FOR EMERGING SYSTEM REQUIREMENTS (AX, NATF, ASTOVL, SSF)
- IMPROVED LIFE CYCLE COST THROUGH IMPROVED RELIABILITY
- IMPROVED A/C AVAILABILITY

TECHNOLOGIES:

- FILM-RIDING FACE SEALS:
  - HYDRODYNAMIC, HYDROSTATIC
- BRUSH / FIBER SEALS
- ABRADABLE SEALS



GOALS:

- NO FORMAL IHPTET GOALS, CONTRIBUTES TO COMPRESSOR & TURBINE GOALS.

	PH I	PH 2	PH 3
TEMPERATURE (F)	800	900	1200
SPEED (FPS)	700	850	1200
WEIGHT	- 5 %	- 10 %	- 20 %

IHPTET/S&T RELIANCE JDL SYSTEM PAYOFFS:

	PH I	PH II	PH III
TIME ON STATION	+1.8%	+3.0%	+ 6 %
RANGE	+ 2 %	+ 4 %	+ 7 %
PAYLOAD	+ 18 %	+ 35 %	+ 50 %
FN / WT	+5.2%	+11.1%	+25.%

MECHANICAL SYSTEMS PROJECT
GAS PATH SEALS

TRENTON, NEW JERSEY

HIGH PERFORMANCE CD FILM-RIDING FACE SEAL

CONTRACTOR: ALLISON

CONTRACT NO.: N00140-39-C-2728

COST: $460 K

OBJECTIVE: DEVELOP/DEMO FILM RIDING CD FACE SEAL° FOR VERY HIGH PRESSURE RATIO PHASE II ENGINES.

GOALS:
- 1200 F AIR
- 800 FPS
- 600 PSID

MECHANICAL SYSTEMS PROJECT
GAS PATH SEALS

TRENTON, NEW JERSEY

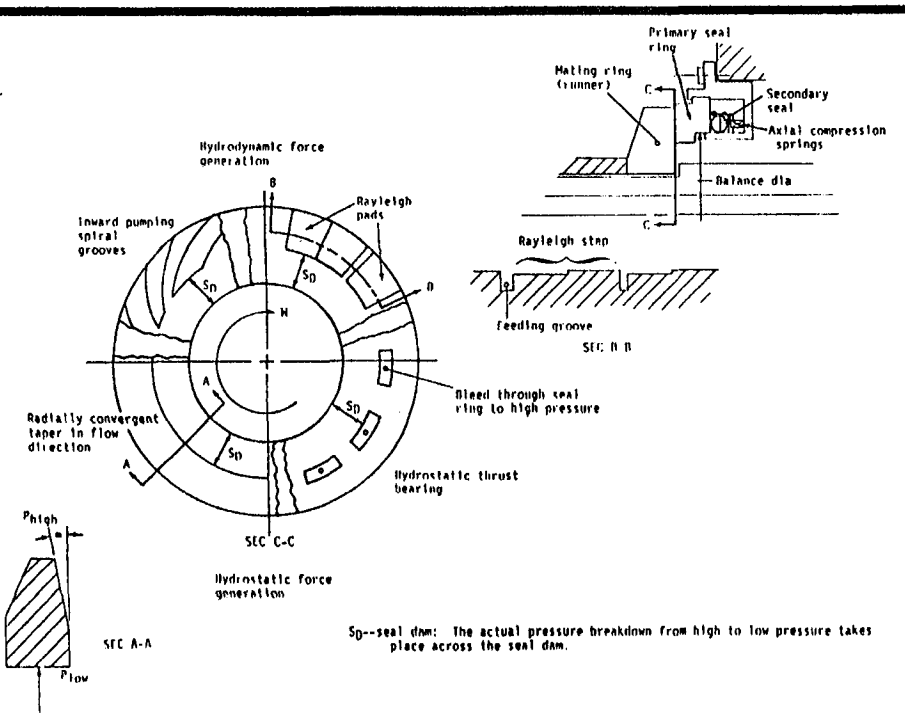
APPROACH: APPLY FILM-RIDING FACE SEAL CONCEPT TO PM II C.D. APPLICATION, USING IMPROVED DESIGN ANALYTICS, IMPROVED MATERIALS ASSESS MULTIPLE LIFT FEATURES, FABRICATE & TEST

TECHNOLOGIES:
- TRANSIENT DYNAMIC FILM ANALYSIS
- SPIRAL GROOVE & RAYLEIGH PAD LIFT GEOMETRIES
- SILICON CARBIDE PRIMARY RING
- IMPROVED PRESSURE BALANCE

ADVANCED BEYOND SOA: REPLACES MULTIPLE LABYRINTH STAGES AT OVER AN ORDER OF MAGNITUDE LESS LEAKAGE

MECHANICAL SYSTEMS PROJECT

TRENTON, NEW JERSEY



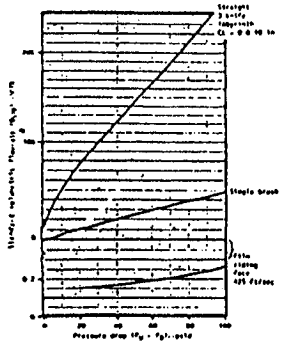
Sp--seal dam: The actual pressure breakdown from high to low pressure takes place across the seal dam.

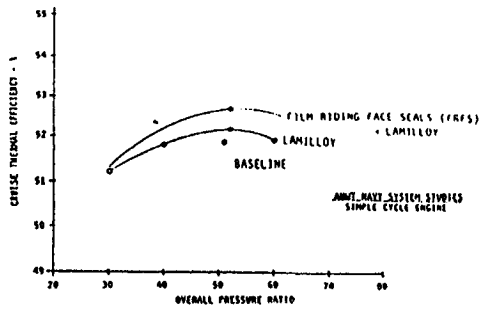
MECHANICAL SYSTEMS PROJECT
GAS PATH SEALS

TRENTON, NEW JERSEY

TRANSITION/
APPLICATION:
- PHASE II JTAGG
- APPLICABLE TO ANY HIGH PRESSURE RATIO MACHINE

PAYOFFS:
- SIGNIFICANT CYCLE EFFICIENCY BENEFITS
  - + 0.5 % THROUGH REDUCED LEAKAGE





MECHNICAL SYSTEMS PROJECT
GAS PATH SEALS

TRENTON, NEW JERSEY

PROGRESS/STATUS:

- FABRICATION OF BOTH SEALS COMPLETE
- STATIC CAL. TESTING OF BOTH SEALS COMPLETE
  - VERY LOW LEAKAGE
- DURING EVALUATION OF CRANE SEAL - RIG INDUCED RUB OCCURRED - SEAL OK; REWORKABLE
- KAYDON SECONDARY SEAL FAILURE OCCURRED AWAITING REVISED HARDWARE