AIR FORCE SEAL ACTIVITIES

Ellen R. Mayhew
Aero Propulsion & Power Directorate
Wright Laboratory
Wright-Patterson Air Force Base, Ohio

Seal technology development is an important part of the Air Force's participation in the Integrated High Performance Turbine Engine Technology (IHPTET) initiative, the joint DOD, NASA, ARPA, and industry endeavor to double turbine engine capabilities by the turn of the century. Significant performance and efficiency improvements can be obtained through reducing internal flow system leakage, but seal environment requirements continue to become more extreme as the engine thermodynamic cycles advance towards these IHPTET goals. Brush seal technology continues to be pursued by the Air Force to reduce leakage at the required conditions. Likewise, challenges in engine mainshaft air/oil seals are also being addressed. Counter-rotating intershaft applications within the IHPTET initiative involve very high rubbing velocities. This presentation briefly describes past and current seal research and development programs and gives a summary of seal applications in demonstrator and developmental engine testing.

OUTLINE

- INTRODUCTION - INTEGRATED HIGH PERFORMANCE TURBINE ENGINE TECHNOLOGY (IHPTET) INITIATIVE
- SECONDARY GAS PATH SEALS
  - PAST R&D PROGRAMS
  - CURRENT R&D PROGRAMS
  - DEMONSTRATOR ENGINE APPLICATIONS
  - F119 ENGINE APPLICATIONS
- MAINSHAFT AIR/OIL SEALS
  - PAST R&D PROGRAM
  - CURRENT R&D PROGRAM
  - DEMONSTRATOR ENGINE APPLICATIONS
- TECHNOLOGIES OF FUTURE INTEREST
- SUMMARY

IHPTET INITIATIVE

- GOAL: DOUBLE TURBINE ENGINE PROPULSION CAPABILITY BY THE TURN OF THE CENTURY
  - FIGHTER/ATTACK ENGINE GOALS:
    - FN/WT + 100%
    - FUEL CONSUMPTION - 40%
  - SIMILAR TURBOSHAFT/PROP AND EXPENDABLE ENGINE GOALS
- SIGNIFICANT SECONDARY FLOW IMPACT ON ENGINE PERFORMANCE
  - HPC: EFF +4.4% ==> TIT -85F OR FN +7.6%
  - HPT: EFF +4.2% ==> TIT -93F OR FN +9.7%
  - REDUCE/ELIMINATE LPT COOLING AIR
- SECONDARY FLOWS GROUPED UNDER COMPRESSOR TECHNOLOGY
  - GOAL OF 60% LEAKAGE REDUCTION
  - NEARLY 20% HPC T/W , 10% HPC FUEL BURN OBJECTIVES
- MAINSHAFT SEAL TECHNOLOGY FOR SHAFT SPEED REQUIREMENTS
  - GOAL OF 50% SPEED INCREASE

SECONDARY GAS PATH SEALS

PAST R&D PROGRAMS

- TEXAS A&M: BRUSH SEAL ROTORDYNAMICS
  - LAST STAGE OF SEAL GROUP DEVELOPS HIGHER DELTA P
  - LEAKAGE INCREASES SLIGHTLY WITH INLET TANGENTIAL VELOCITY
  - CROSS-COUPLED STIFFNESS COEFFICIENT VERY STABLE
  - EXTREMELY STABLE WHIRL FREQUENCY RATIO
  - ROTORDYNAMICS INDEPENDENT OF SEAL SPACING/INLET TANGENTIAL VELOCITY
  - HOWEVER, BRUSH SEAL DIRECT DAMPING IS LESS THAN LAB SEAL

  - BRUSH SEAL WILL GENERALLY IMPROVE ROTOR DYNAMIC CHARACTERISTICS IF LAB SEAL IS DESTABILIZING THE ROTOR DUE TO FLUID PRESWIRL
    - LOWER DAMPING OF BRUSH SEALS MUST ALSO BE CONSIDERED

  - REPORT #: WL-TR -92-2125 (REVISED)

SECONDARY GAS PATH SEALS
PAST R&D PROGRAMS

- EG&G FCTG: BRUSH SEAL DEVELOPMENT PROGRAM
  - BRISTLE ANGLE, LENGTH, STIFFNESS, STAGING, PACKWIDTH EFFECTS ON HYSTERESIS, DELTA P, LEAKAGE; TRIBOPAIR WEAR
  - INCREASED PACKWIDTH GAVE HIGHER DELTA P/LOWER LEAKAGE
  - MULTIPLE STAGE BRUSH SEAL PERFORMANCE
    - LEAKAGE REDUCTION
    - UNEQUAL PRESSURE DISTRIBUTION
      - CONTROL WITH MIXED PACKWIDTHS/STIFFNESSES
      - HIGHER PACKWIDTH SEALS MOST EFFECTIVE
  - LOW FRICTION/WEAR/OXIDATION TRIBOPAIRS IDENTIFIED
  - TESTING VERIFIED REDUCED HYSTERESIS IN ADVANCED DESIGNS
  - FULL SCALE HARDWARE DELIVERED FOR DEMO ENGINE TEST
  - REPORT #: WL-TR-93-2029 (DESIGN GUIDE)
  - REPORT #: WL-TR-93-2064 (FINAL REPORT)

SECONDARY GAS PATH SEALS
CURRENT PROGRAMS

- EG&G FCTG
  - ADVANCED BRUSH SEAL DEVELOPMENT PROGRAM
- PRATT & WHITNEY
  - HIGH SPEED BRUSH SEAL DEVELOPMENT PROGRAM
- TECHNETICS CORPORATION
  - CERAMIC BRUSH SEALS

ADVANCED BRUSH SEAL DEVELOPMENT PROGRAM
EG&G FCTG

- OBJECTIVE: DEVELOP A COMPREHENSIVE DESIGN METHODOLOGY FOR APPLICATION OF ADVANCED, HIGH PERFORMANCE BRUSH SEALS IN MAN-RATED ENGINES

- APPROACH:
  - EXPERIMENTAL/CFD CHARACTERIZATION OF SEAL DESIGN
    - MAXIMIZE SINGLE- AND MULTI-STAGE DELTA P CAPABILITY
    - ACCOMMODATE LARGE AXIAL AND RADIAL EXCURSIONS
    - EVALUATE NON-CONTACTING BRUSH SEAL FEASIBILITY
  - TRIBOPAIR TESTING AND EVALUATION AT ELEVATED CONDITIONS

- ACCOMPLISHMENTS:
  - INITIAL WEAR TESTING OF "LOW HYSTERESIS" DESIGNS SUCCESSFUL
    - INITIAL TESTING TOWARD ACCOMMODATION OF EXCURSIONS
    - HIGH SPEED TESTING THIS MONTH
  - FOUR HIGH PRESSURE SEAL DESIGNS BEING FABRICATED
  - BRISTLE MOVEMENT/HYSTERESIS OBSERVED IN OPTICAL VIEWING
  - CFD MODELING OF BRISTLE TIP LIFT-OFF IN PROGRESS

HIGH SPEED BRUSH SEAL DEVELOPMENT PROGRAM
PRATT & WHITNEY

- OBJECTIVE: DEMONSTRATE HIGH-SPEED AND HIGH-TEMPERATURE OPERATION OF ADVANCED BRUSH SEALS FOR IHPTET PHASE II DEMONSTRATOR ENGINES

- APPROACH:
  - APPLICATION STUDY OF IHPTET PHASE II ENGINE/MISSION FLIGHT CYCLE FOR SURFACE SPEED AND TEMPERATURE REQUIREMENTS
  - DESIGN/FABRICATE/RIG TEST BRUSH SEALS TO VERIFY THEIR CAPABILITY TO OPERATE AT IHPTET PHASE II CONDITIONS

- ACCOMPLISHMENTS:
  - APPLICATION STUDY COMPLETED
  - PRELIMINARY DESIGN OF BRUSH SEAL CONCEPTS COMPLETED
  - RIG ADAPTIVE HARDWARE DESIGN IN PROGRESS

CERAMIC BRUSH SEALS
TECHNETICS CORPORATION

- OBJECTIVE: DEVELOP "HYBRID" CERAMIC BRISTLE/METALLIC HOLDER BRUSH SEALS FOR GAS TURBINE ENGINES CAPABLE OF OPERATING AT IHPTET PHASE II AND PHASE III TEMPERATURES

- APPROACH:
  - PERFECT THE MANUFACTURING METHODS OF THE "HYBRID" SEAL
  - CONDUCT RIG TESTING FOR PERFORMANCE, ROTORDYNAMICS, AND WEAR
  - FABRICATE HYBRID SEAL FOR TEST IN A DEMONSTRATOR ENGINE

- PROGRESS:
  - NEW START

SECONDARY GAS PATH SEALS
DEMONSTRATOR ENGINE BRUSH SEALS

- TESTING TO DATE
  - TURBINE AND COMPRESSOR APPLICATIONS
  - HAYNES 25 BRISTLES
  - CHROME CARBIDE OR ALUMINUM OXIDE COATINGS
  - 20-80% REDUCTION IN LEAKAGE OVER LAB SEALS
  - GENERALLY GOOD DURABILITY

- FUTURE TESTING
  - PLANNED FOR ALL DEMO ENGINES (ATEGG, JTDE, JTAGG, JETEC)
  - HIGHER SURFACE SPEEDS, TEMPERATURES
  - EXPANDED ARRAY OF BRISTLE AND COATING MATERIALS
  - ADVANCED CONFIGURATIONS

SECONDARY GAS PATH SEALS

F119 ENGINE BRUSH SEALS

- INITIAL FLIGHT RELEASE
  - 4 STATIC SEALS

- FULL FLIGHT RELEASE
  - HPT (3 LOCATIONS)
  - LPT (4 LOCATIONS)
  - COMPRESSOR DISCHARGE LOCATION

MAINSHAFT AIR/OIL SEALS

PAST R&D PROGRAM

- PRATT & WHITNEY: HIGH SPEED SEAL DEVELOPMENT

  - MODIFIED CONTROLLED GAP CLEARANCE SEAL

  - 1200 FT/SEC PITCH LINE VELOCITY DEMONSTRATED
  - 60 PSID, 450 F
  - AIR LEAKAGE AS LOW AS 54 LBS/HR AT 1050 FT/SEC, 50 PSID
  - SUCCESSFUL 80 HR ENDURANCE TEST WITH VERY LITTLE WEAR

  - REPORT #: WL-TR-92-2102

MAINSHAFT AIR/OIL SEALS
CURRENT PROGRAM

GENERAL ELECTRIC: MAINSHAFT AIR/OIL SEAL PROGRAM

- OBJECTIVE: DEVELOP AN INTERSHAFT SEAL FOR IHPTET PHASE II DEMONSTRATOR ENGINE CONDITIONS (900 FPS/900F/50 PSID)

- APPROACH:
  - ESTABLISH PHYSICAL/TRIBOLOGICAL CHARACTERISTICS OF SEAL MATERIALS
  - SELECT BEST MATERIALS FOR APPLICATION
  - DESIGN/FABRICATE/RIG TEST AT IHPTET PHASE II CONDITIONS

- ACCOMPLISHMENTS:
  - HIGH STRENGTH CARBON/CARBON COMPOSITES AND METALLIC/CERAMIC PAIRS CHARACTERIZED
  - CARBON COMPOSITE MATERIAL CHOSEN
  - DETAILED SEAL DESIGNS COMPLETED
    - HYDROSTATIC GAS BEARING SUPPORTED, CONTINUOUS RING CONFIGURATION
  - SEALS FABRICATED/RIG TESTING IN PROGRESS

MAINSHAFT SEALS
DEMONSTRATOR ENGINE APPLICATIONS

- BOTH PROGRAMS TRANSITIONING DIRECTLY INTO THEIR RESPECTIVE CONTRACTOR'S DEMONSTRATOR ENGINE PROGRAMS

SUMMARY

- AF COMMITTED TO DEVELOPING AND TRANSITIONING SEAL TECHNOLOGY
- PUSHING FOR INCORPORATION OF ADVANCED SEAL TECHNOLOGY IN ALL DEMONSTRATOR ENGINES
- WORKING WITH PROGRAM OFFICES TO TRANSITION SEAL TECHNOLOGY TO OPERATIONAL AND DEVELOPMENT ENGINES

FUTURE TECHNOLOGIES

- SECONDARY GAS PATH SEALS:
  - RUB-TOLERANT BRUSH SEAL BACKPLATES
    - NO CATASTROPHIC RUNNER DAMAGE DUE TO BACKPLATE CONTACT IN PRIMARY OR SECONDARY FAILURE EVENTS
    - SOME PROPRIETARY/PATENTED CONCEPTS AVAILABLE
    - INCREASED AF ATTENTION IN THIS AREA
  - INCREASED TEMPERATURE REQUIREMENTS
    - ALL-CERAMIC BRUSH SEALS/ADVANCED COATINGS
  - NON-CONTACTING SEALS
    - NON-CONTACTING BRUSH SEALS
    - OTHERS
  - BRUSH SEAL COMPRESSOR SHROUD (PRIMARY GAS PATH)
    - BLADE TIP LEAKAGE REDUCTION FOR INCREASED EFFICIENCY
    - BLADE DAMPING AUGMENTATION
    - STALL MARGIN IMPROVEMENT
- MAINSHAFT SEALS:
  - INCREASED SPEED AND TEMPERATURE REQUIREMENTS
    - CERAMICS
    - NON-CONTACTING GAS-BEARING FEATURES FOR DURABILITY