2010 UTSR Gas Turbine Industrial Fellowship

Gas Turbine Igniter Design and Ion Sensor Development

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2010 Woodward Fellowship Projects:

- **Gas Turbine Igniter Performance Validation**
- **Microturbine Variable Geometry Injector Redesign**
- **Atomization Nozzle Testing** – Proprietary, Not Covered in this Presentation
- **Ion Sensing Product Development** – Proprietary, Limited Information Provided
- **Component Life Assessment, Spark Erosion Testing** – Proprietary/In Progress

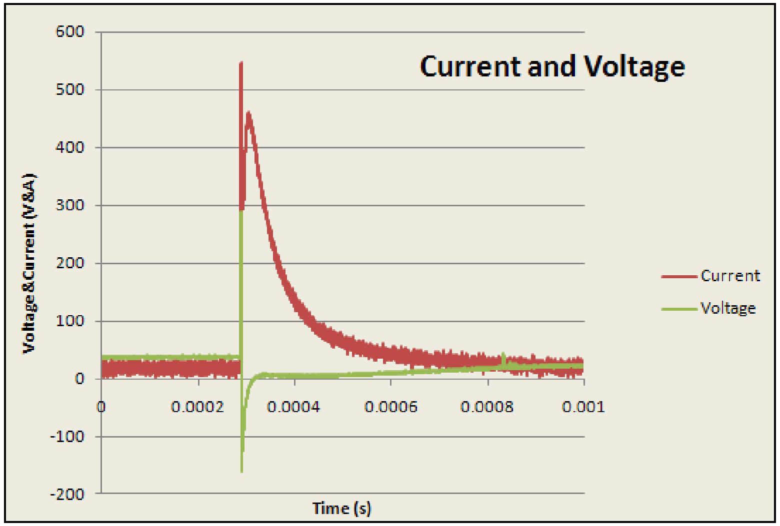
Igniter Performance Validation:

- 6 igniters were returned to Woodward for performance validation
- Parameters Reviewed:
  - Spark Energy
  - Torsional Strength
  - Air Leakage

Igniter Performance Validation

- Using an oscilloscope each returned igniter was sparked repeatedly
- The voltage across the igniter gap as well as the current across the igniter gap were recorded as a function of time
- 10 spark events were averaged to ensure accuracy
- These two signals were multiplied together and integrated as a function of time to determine the total energy released over the spark event.

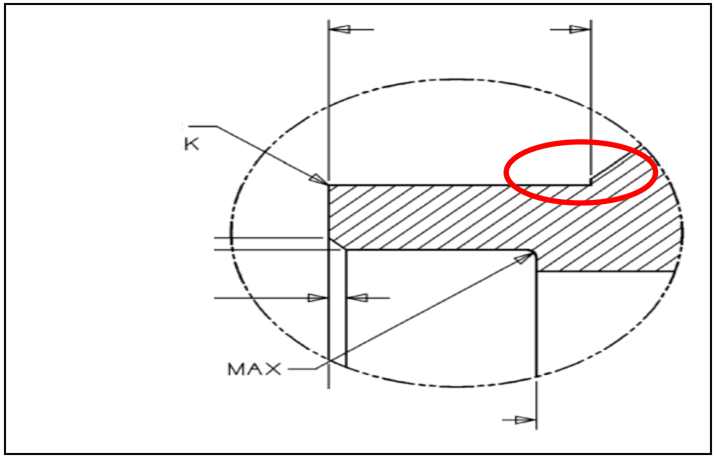
All igniters delivered more energy than was required.



Sample spark signal recorded by the oscilloscope

Igniter Performance Validation

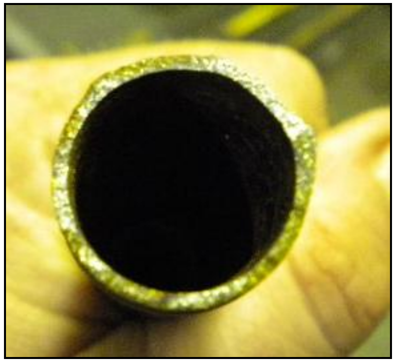
- Torsional strength of igniter tube was a concern
- Component is rated for 30 ft-lb of torque
- High stress at fracture location was caused by low (.005”) radius; therefore high stress concentration factor
- It was found that increasing the radius greatly improves the torsional strength of the component



Location of component failure

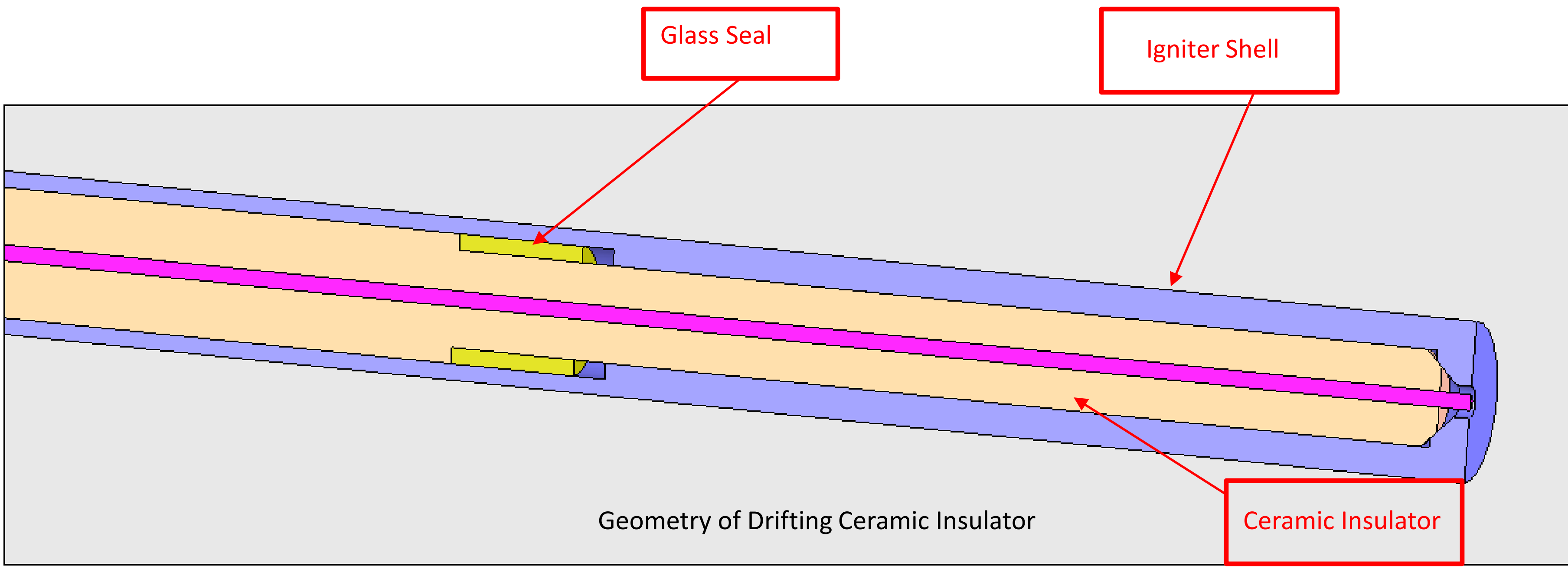
R (in)	K	Yield Torque (ft-lb)
0.005	3	25
0.01	2.4	31
0.05	1.5	50
0.1	1.25	59

Strength variation as a function of minimum radius



Photos of failed component

Igniter Design Validation

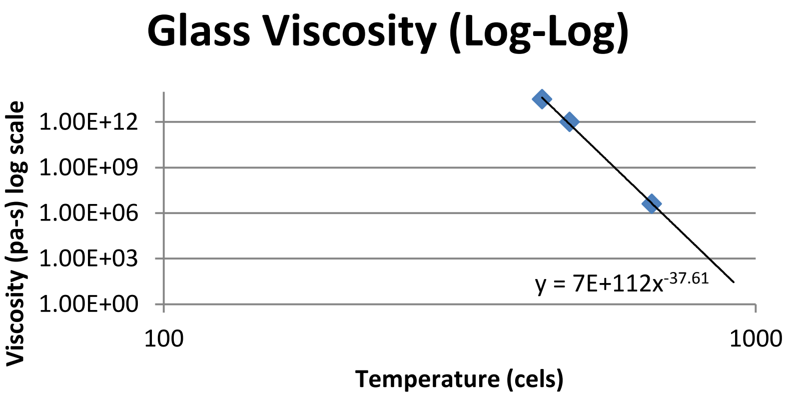
- One potential igniter design institutes the concept of preloading a ceramic insulator against the igniter shell, holding it in place with a glass seal
- Glass seals soften at elevated temperature
- Combustion pressure provides an axial force



Geometry of Drifting Ceramic Insulator

Igniter Design Validation

- Glass viscosity decays exponentially as temp increases



Governing Equation:

$$\tau_{yx} = \frac{dF_x}{dA_y} = \mu \frac{du}{dy}$$

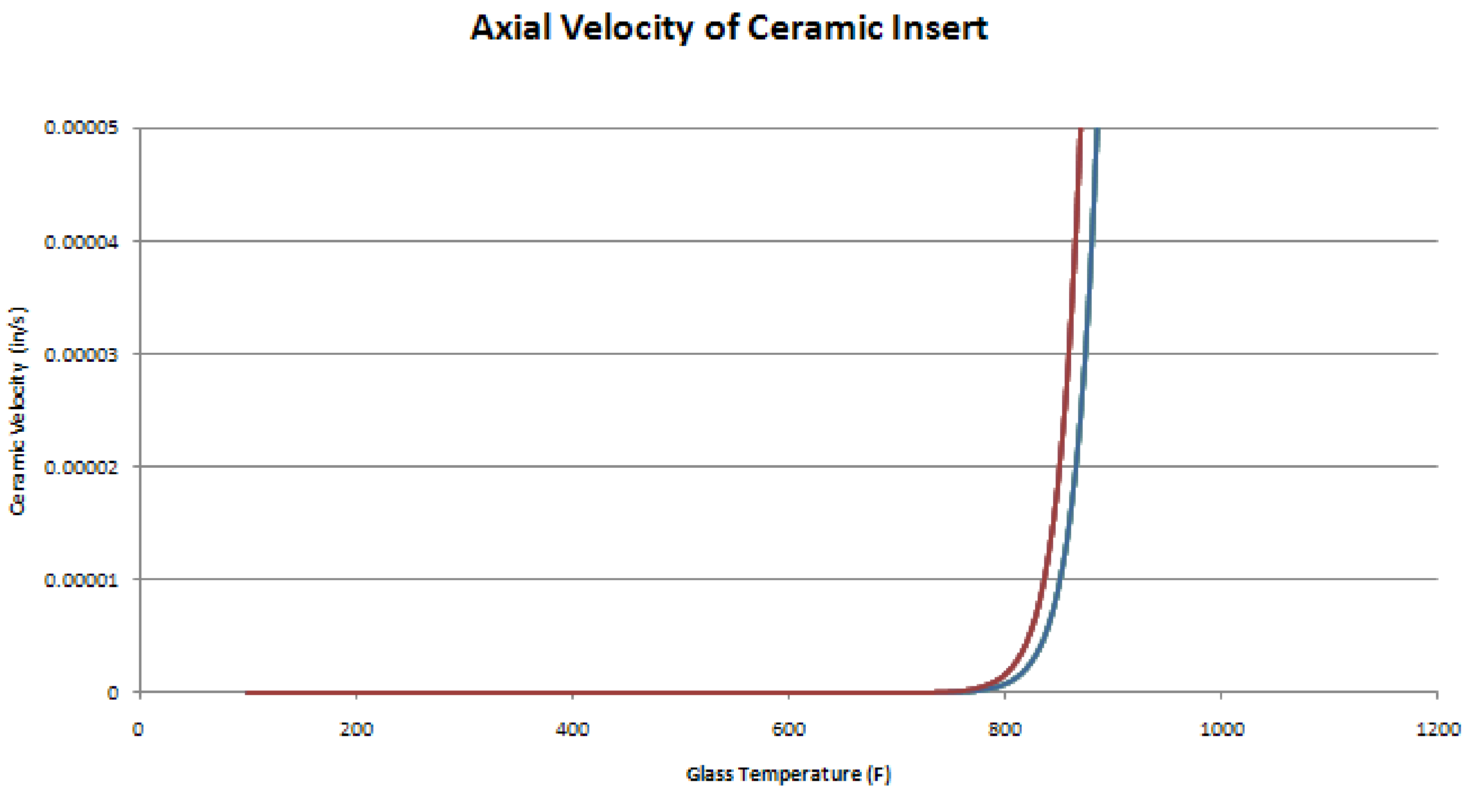
Math Procedure: $\frac{du}{dy} = A \ (Integrating >) U = Ay + B$

Boundary Conditions: @y=thickness u=0 @ y=0 U= velocity of drift

- **Treat the glass seal as a continuous fluid with μ(T)**
- **Since axi-symmetric problem can be approximated as 2-D**
  - **Plane Couette Flow**
    - **Treat the shell as a stationary wall (no slip condition)**
    - **Treat the ceramic as a wall moving with constant velocity**
- **Approximate axial force on ceramic as (Chamber Pressure)*(Area Exposed)**
  - **Estimated as 32 lb on the tip only**
  - **Estimated as 66 lb if applied to the whole glass seal face**

Igniter Design Validation

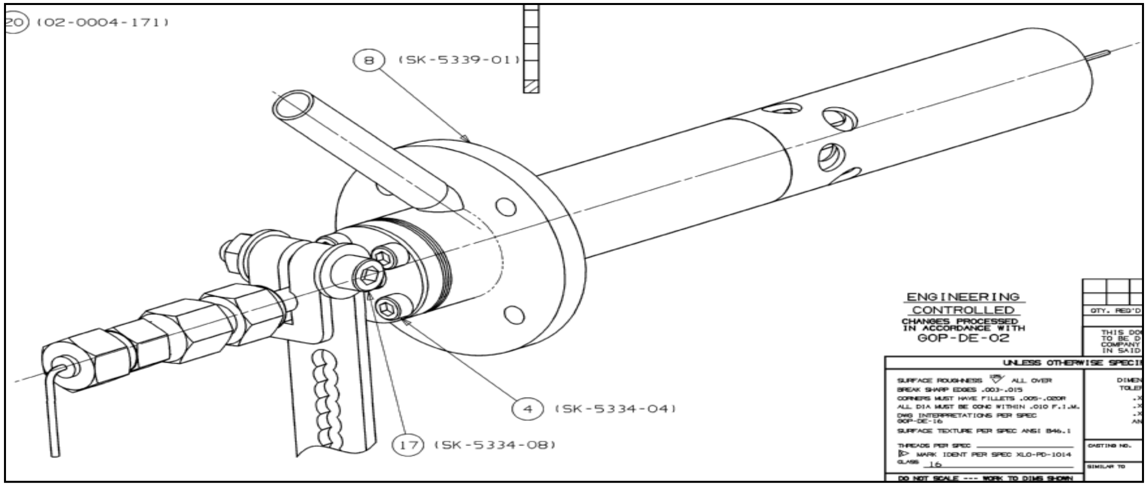
- Red and blue lines denote two loading schemes
- Rapid liquid-solid transition – 1 in/s drift @ 1200 F
- The insulator will drift appreciably at temperatures greater than 800 F
- Drift is primarily a function of material properties



Microturbine Variable Geometry Injector Redesign

- Woodward recruited to design and advise on the topics of fuel injection and ion sensing
- Fuel injectors are variable geometry, gas fuel only
- 6 injectors are installed around the circumference of the combustor
- Injectors experienced binding after prolonged operation
- Under certain operating conditions the ion sensors melted

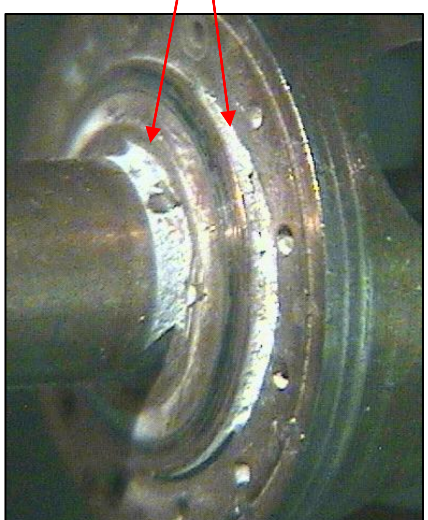
Variable Geometry Injector



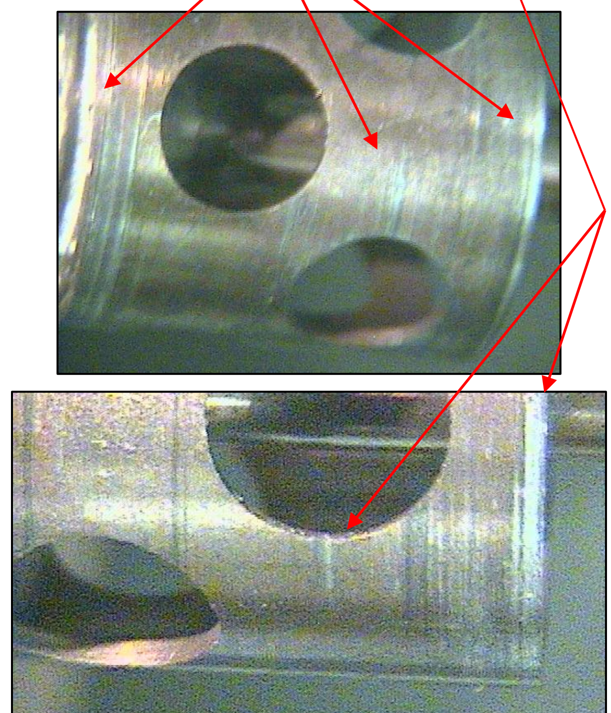
Microturbine Variable Geometry Injector Redesign

- Microscopic examination revealed tangential wear marks on the rotational components
- Visual inspection revealed crystalline deposit on rotating components

Deposit on Fuel Distributor-Centerbody Interface

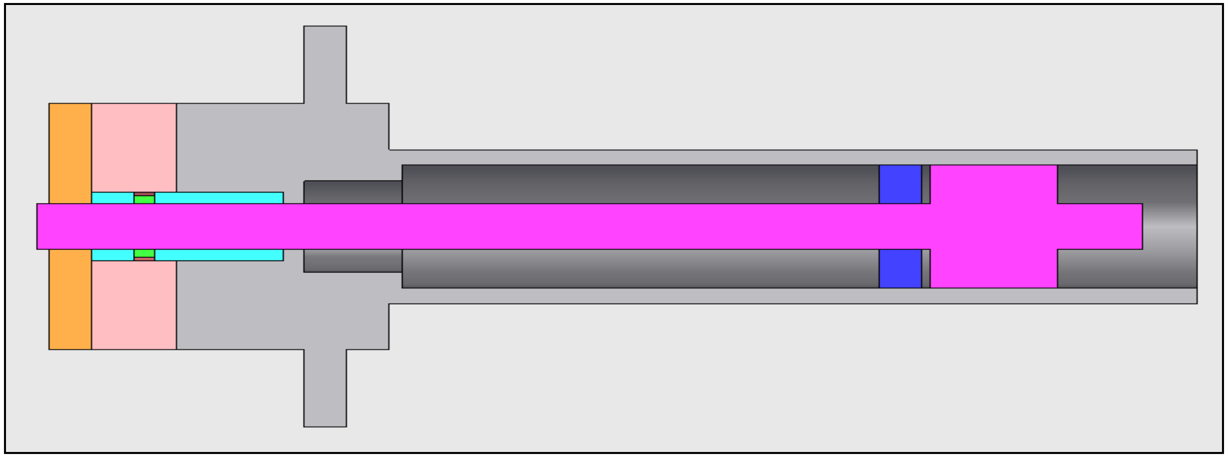


Tangential Wear Marks



Microturbine Variable Geometry Injector Redesign

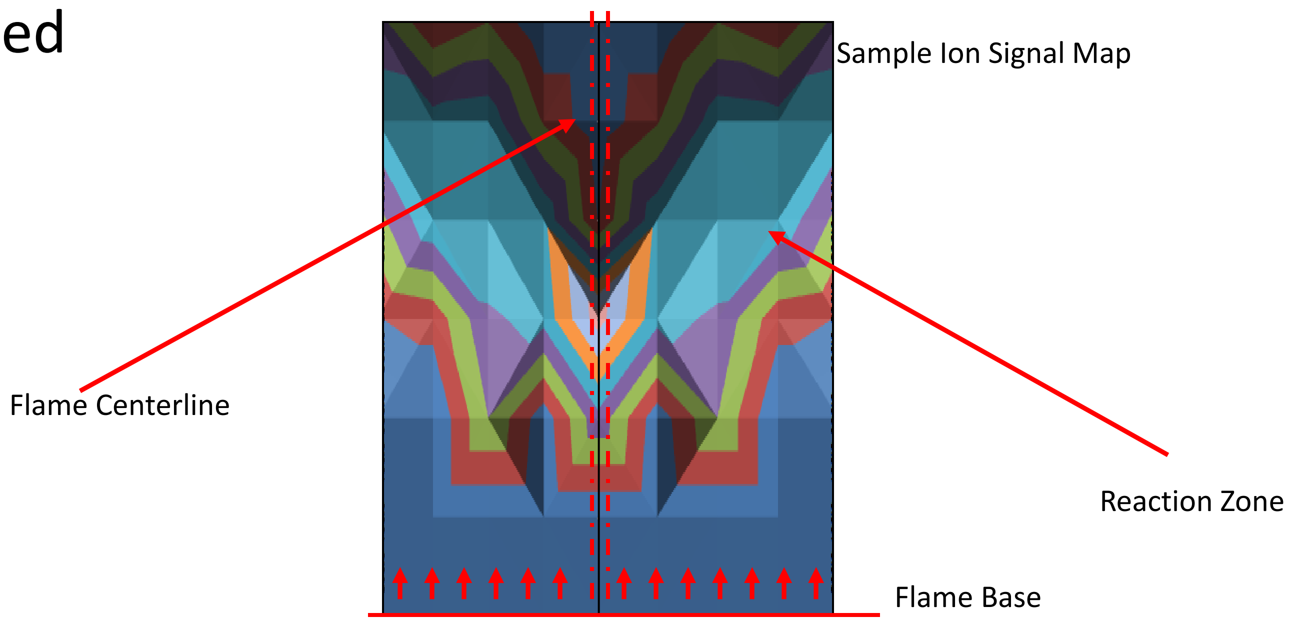
- Potential causes of binding
  - Uneven thermal expansion
    - Spring force in excess (axial) – Decreases from 3.66 lb as component heats
    - Centerbody trapped by tubing (radial) – Loss of 1.7 thou on a 7 thou gap
  - Buildup of crystalline deposit – increased friction
  - Improper installation
- Final Conclusion
  - Uneven thermal expansion/oblongation due to injector orientation in the engine
- Corrective actions:
  - Increase diametric clearance of sieve by .002"
  - Remove spring
  - Remove fuel distributor – sieve contact point



Updated Design

Ion Sensing Product Development

- An Ion Sensor is being developed for the purpose of flame mapping
- Ion sensing signal is characterized by a significant amount of noise and/or baseline drift
- Methods were devised LabVIEW code was written to analyze ion sensing data and create a map of the flame
- A best method was determined and future test plans were devised



Conclusion:

- The Woodward fellowship combined a number of important aspects
  - Product Development
  - Design Validation
  - Design Revision
  - Mathematical Modeling
  - Hands-On Laboratory Testing
- The fellowship culminated with a 51 slide, hour-long presentation to the engineering staff.
- Woodward and Louisiana State University are moving forward with the design of a custom igniter for LSU, exhibiting developments in Industry-University relations.

Acknowledgements:

- Special Thanks to:
  - Mike Hackenberg
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