Improved Flare Tip Design

P. Gogolek

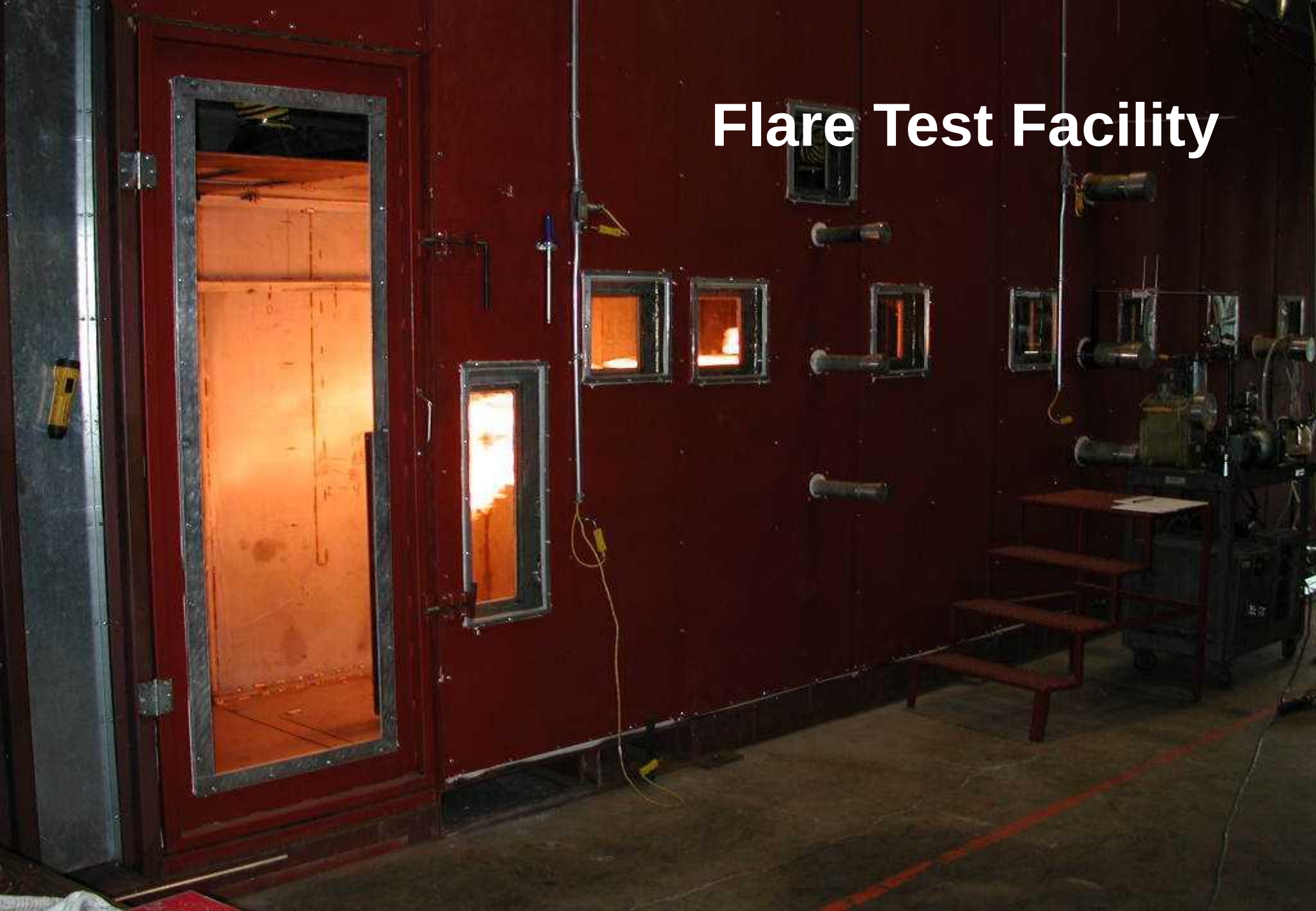
Flare Test Facility

CETC – Ottawa

2004 PTAC Air Issues Forum, Calgary, Alberta

The Team

- Skip Hayden – group leader.
- Peter Gogolek – lead scientist.
- Cory Balderson – technician.
- Sean Salusbury, Bartosz Bober, Steve Bédard – co-op students.
- David Faguy – data acquisition and instrumentation.
- Steve Bethune – controls.
- Doug Percy – analytical instruments.


Flare Test Facility

Flare Test Facility Description

- Allows testing realistic, near full scale solution gas flares in single-pass flare test facility.
- Working section has adjustable ceiling (5’ to 8.5’), 4’ wide, 27’ long.
- High capacity variable speed fan.
- Sampling ports along working section, in stack.
- Windows along working section, back end.
- Walls, floor, ceiling all air cooled.

FTF Description (ctd)

- Fuels: NG, Propane, gasoline, inerts
- Fuel Flow: up to 2 MMBTU/h (g), 8 gal/h (l)
- X-wind speed: 5 to 45 km/h
- Flare pipe size: 1”, 2”, 3”, 4”, 6” dia.
- Various appurtenances.
- Turbulence generating grids.
- Continuous Gas Emission Measurements :
  O_2, CO, CO_2, CH_4, NMHC.

Design Constraints for Flare Tips

- Low fuel gas delivery pressure.
- No utilities available (ie, steam or electricity).
- Exposed to wind, from all directions
- Handle extremes of temperature
- Resist corrosion
- Handle variable feed without performance degradation.
- Low capital cost.
- No operators required.

Design Objectives

- Performance equal to or better than utility flare at low wind speed.
  - Performance = conversion efficiency, fuel slip, smoking.
- Significant improvement at high wind speed.
- No increase in trace emissions.

Wind Conditions

- Broad range of average wind speed.
  - Frequent low wind (< 1 km/h).
  - Significant high wind (>20 km/h).
- Surface layer of atmospheric boundary layer.
- Flow well characterised.
  - Turbulent shear flow.
  - Mean velocity, intensity vary with height.

Flare Performance

- Wind speed:
  - Wake-stabilised flame.
  - Decreases efficiency.
  - Decreases sooting.
- Turbulence:
  - Increased intensity decreases efficiency.
  - Increases methane slip.
- Fuel composition:
  - NG least efficient.
  - Increased efficiency with fraction of propane.

Scaling Criteria

Buoyant plume parameter

$$BP = U_w/(g\ D_p\ V_f)^{1/3}$$

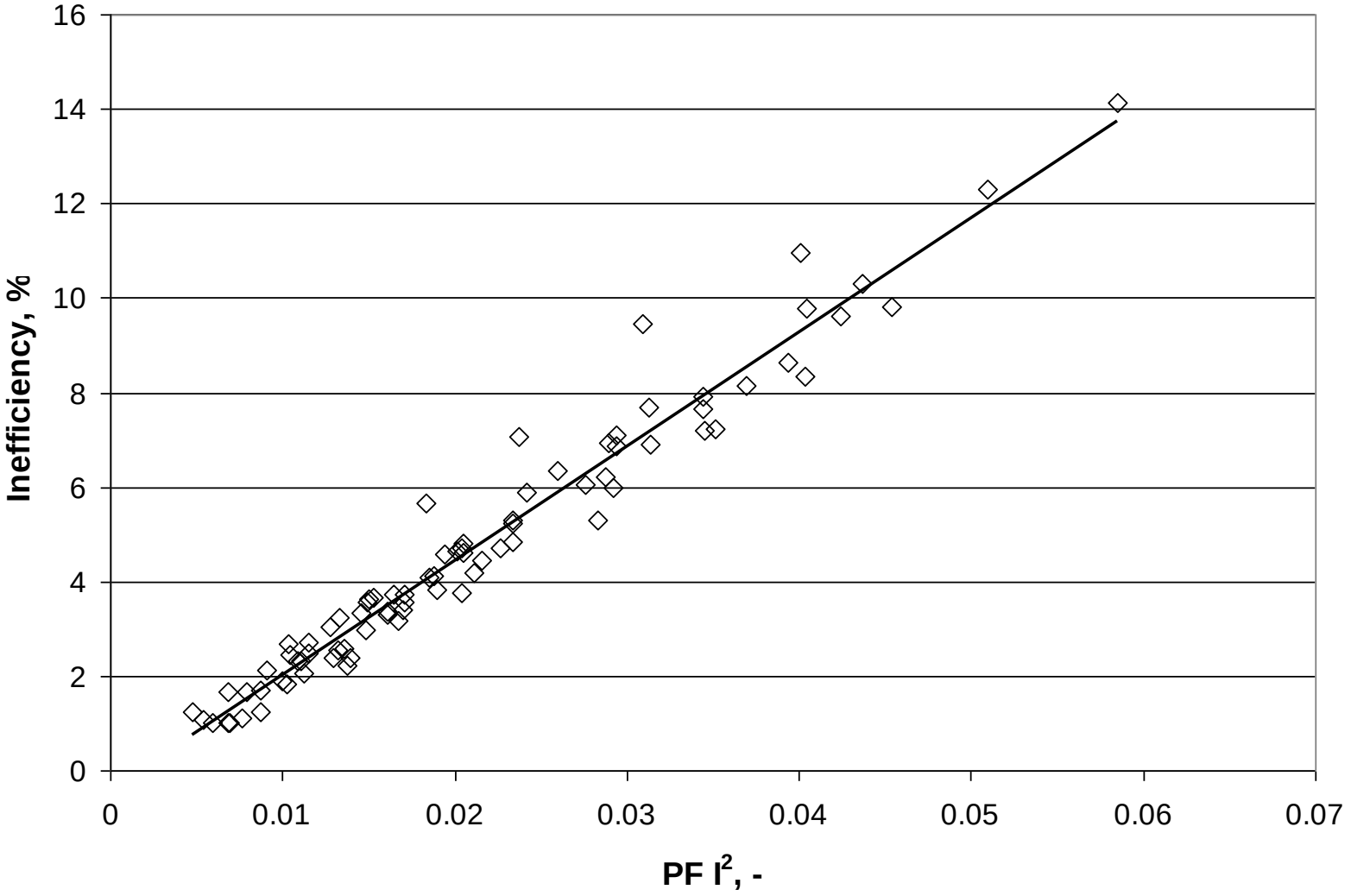
Power Factor

$$PF = (\rho_a\ D_p^2\ U_w^3/m_f\ LHV)^{1/3}$$

Intensity of turbulence

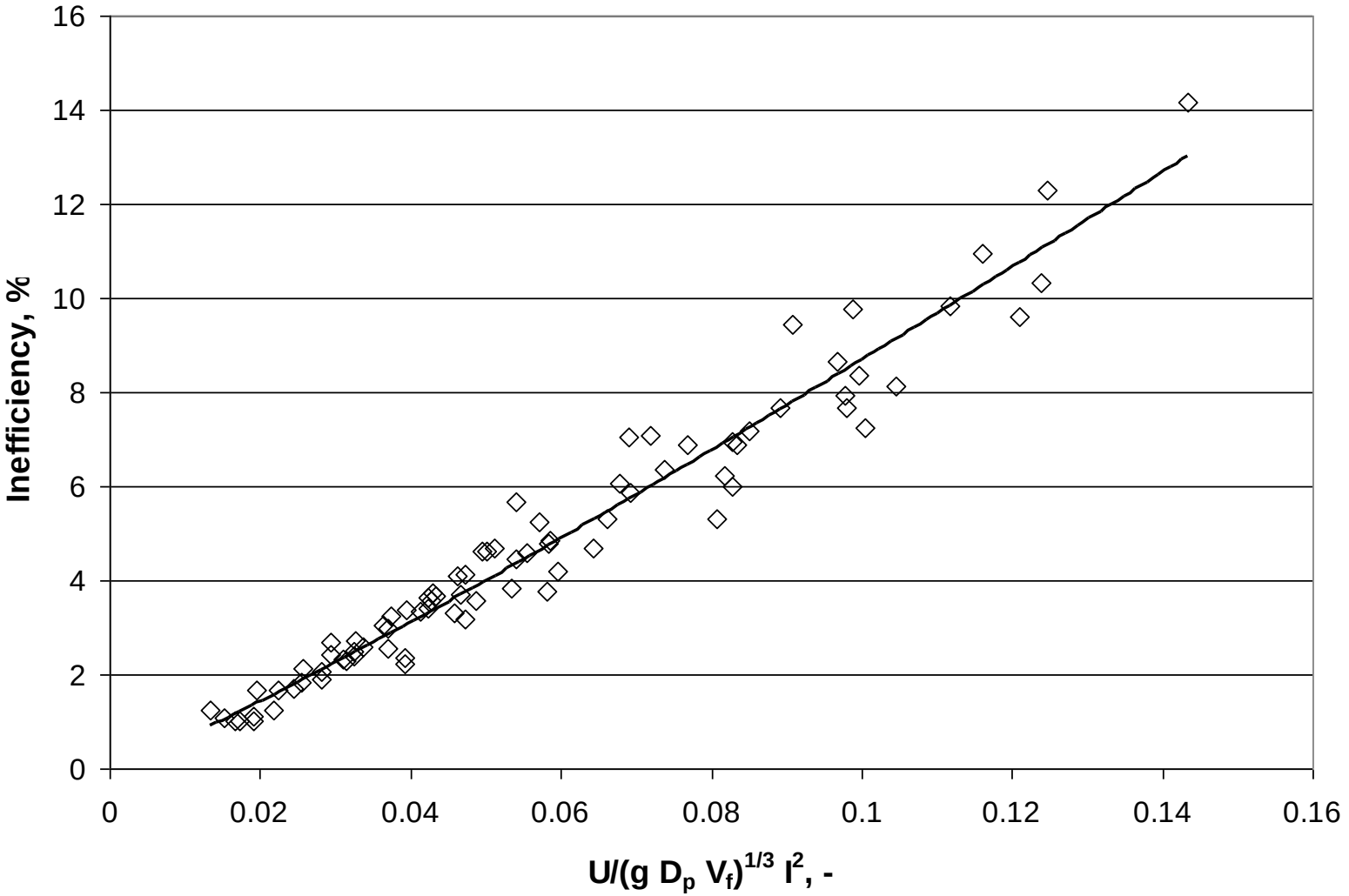
$$I = u'/U_w$$

Conversion inefficiency – correlation of wind speed and turbulence, fuel flow, pipe size



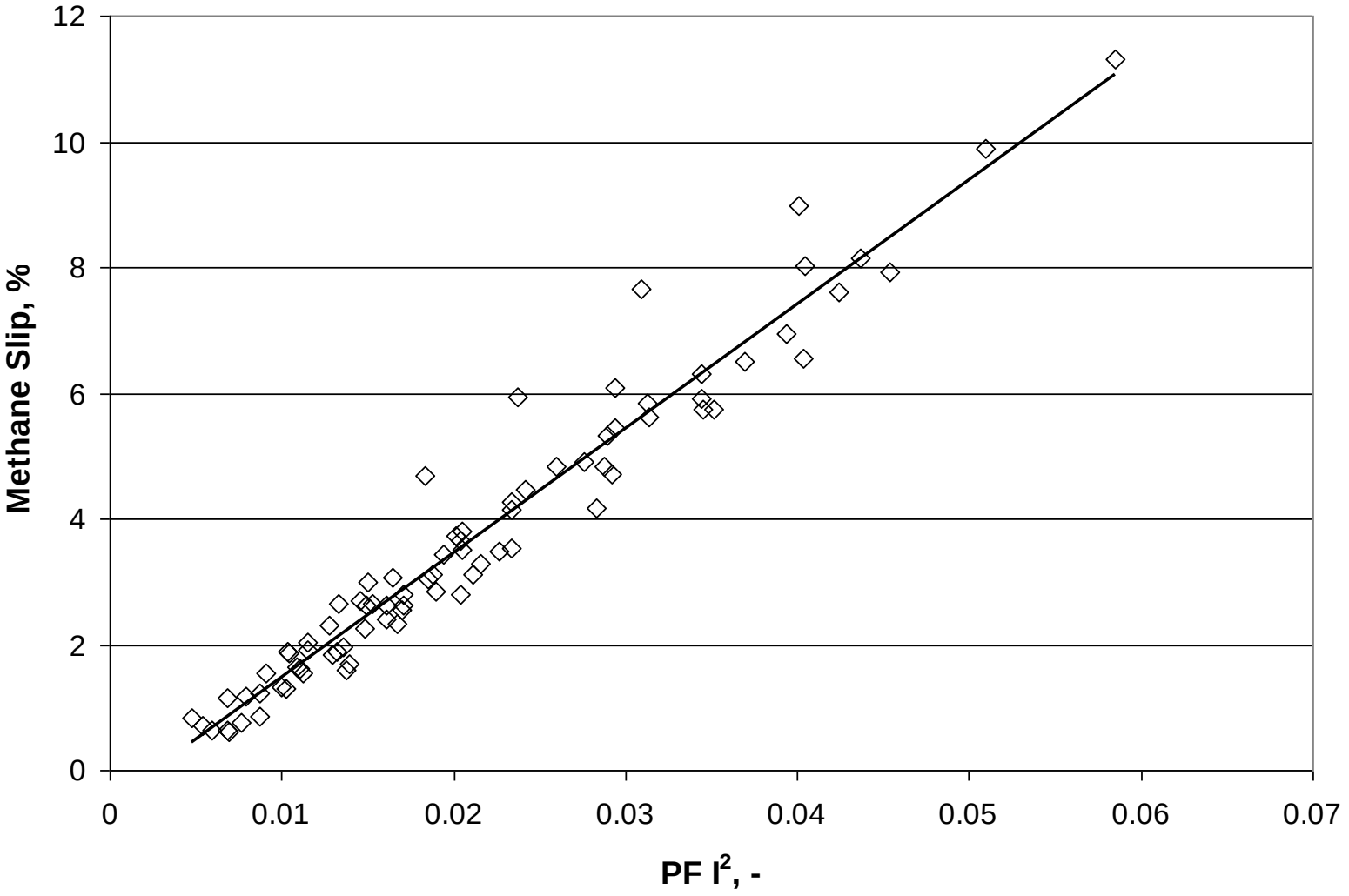
Includes 2 levels of turbulence, 4" and 6" pipe, 4 levels of fuel flow; NG only

Conversion inefficiency – correlation with Buoyant Plume parameter



Same data set, equally good correlation

Methane slip is similarly correlated



Same data set as for inefficiency

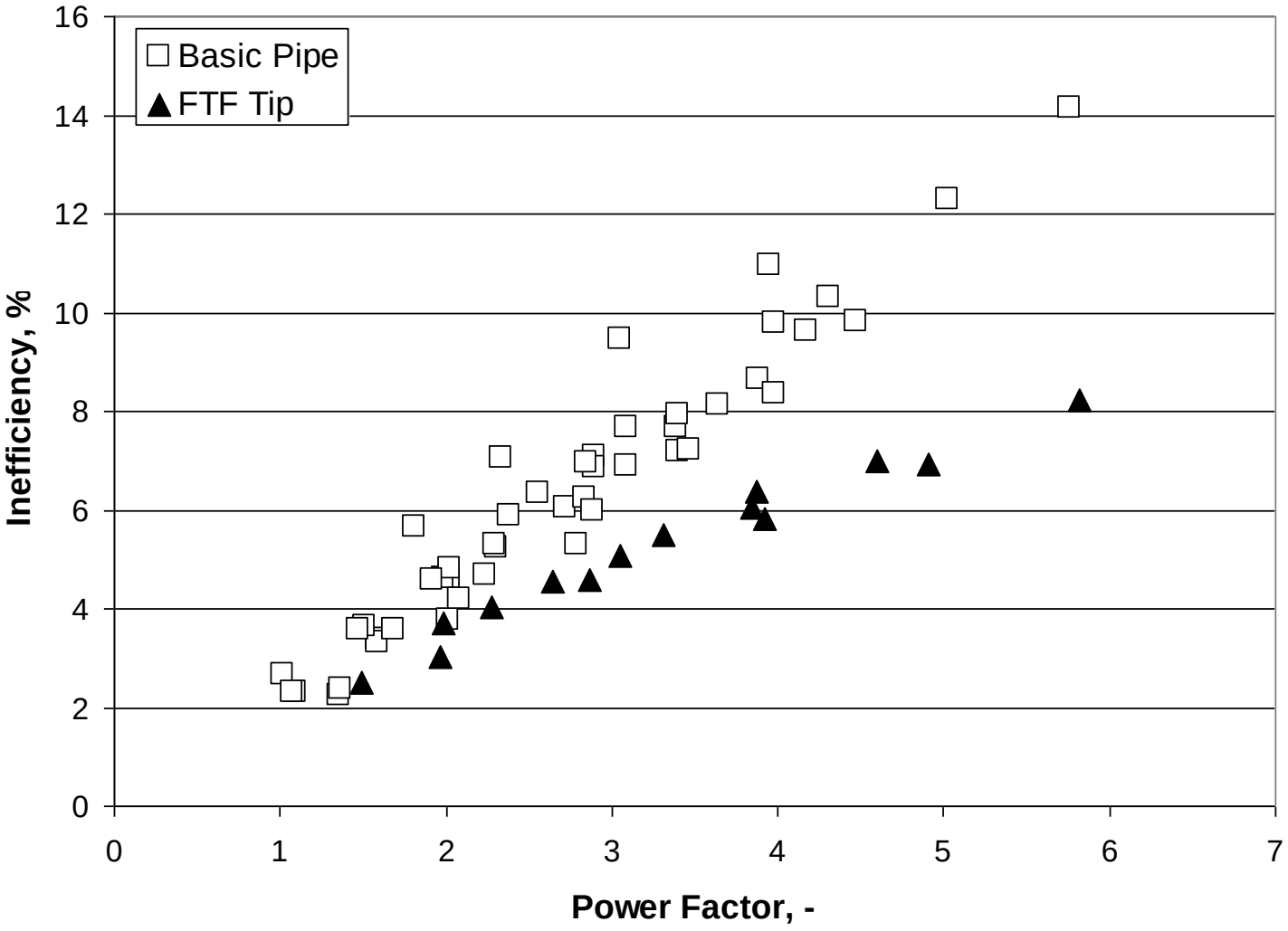
Flare Emissions

- Fuel slip is primary source of emissions.
  - Methane ~80% of inefficiency.
  - CO makes up the rest.
- Trace emissions:
  - VOCs at very low levels.
  - Stripping of less reactive vapours with liquid injection.
- Caveat: non-sooting flames; no sour gas.

New Tip Designs

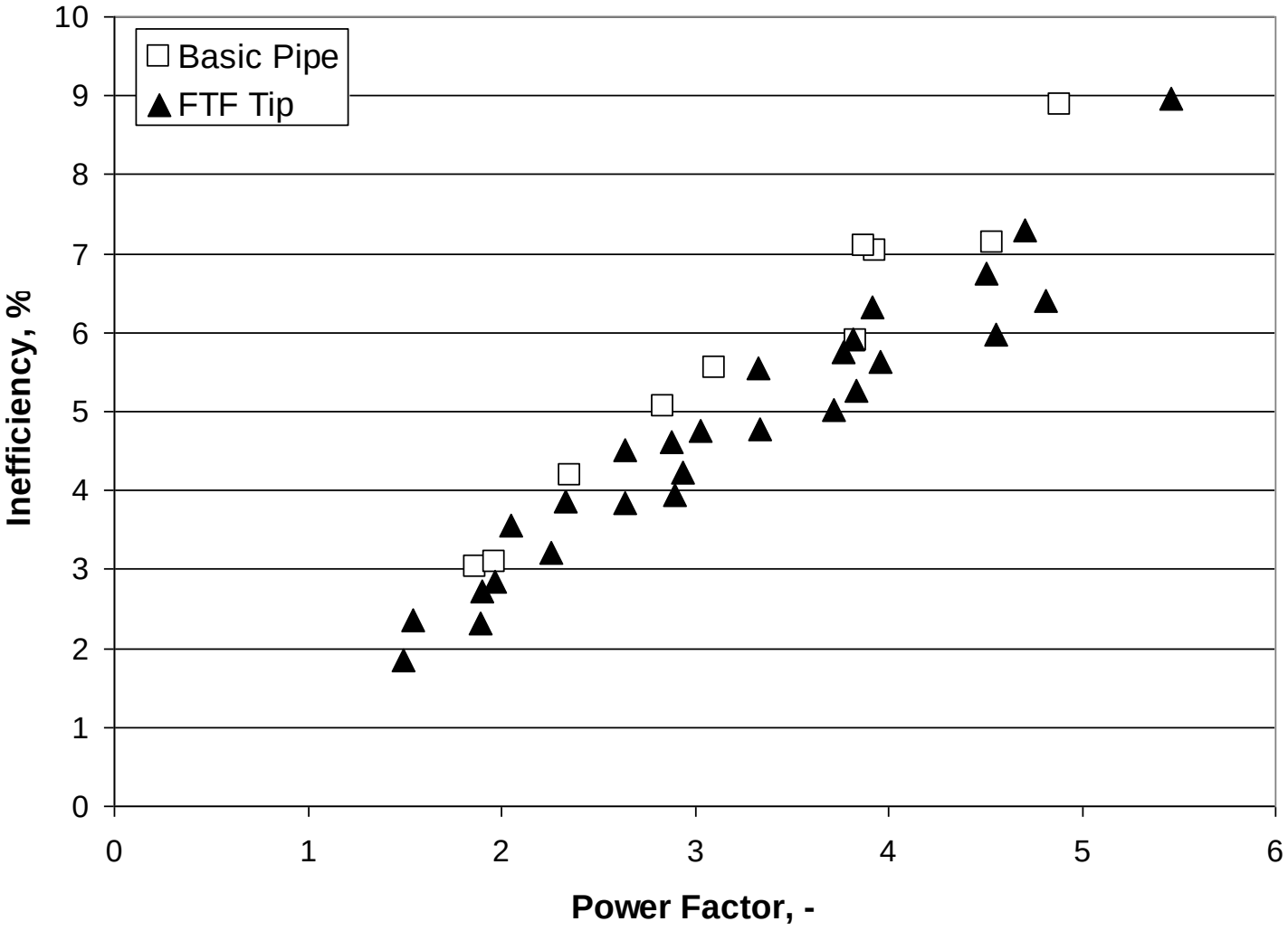
- 3 tip designs fabricated for testing.
  - All fit on 4” pipe.
- Screening tests for comparison to basic pipe and ranking designs.
  - High intensity turbulence
  - Low and high fuel flow rates
- One tip clearly the best, further testing and scale-up to 6” tip.

New tip shows significant improvement



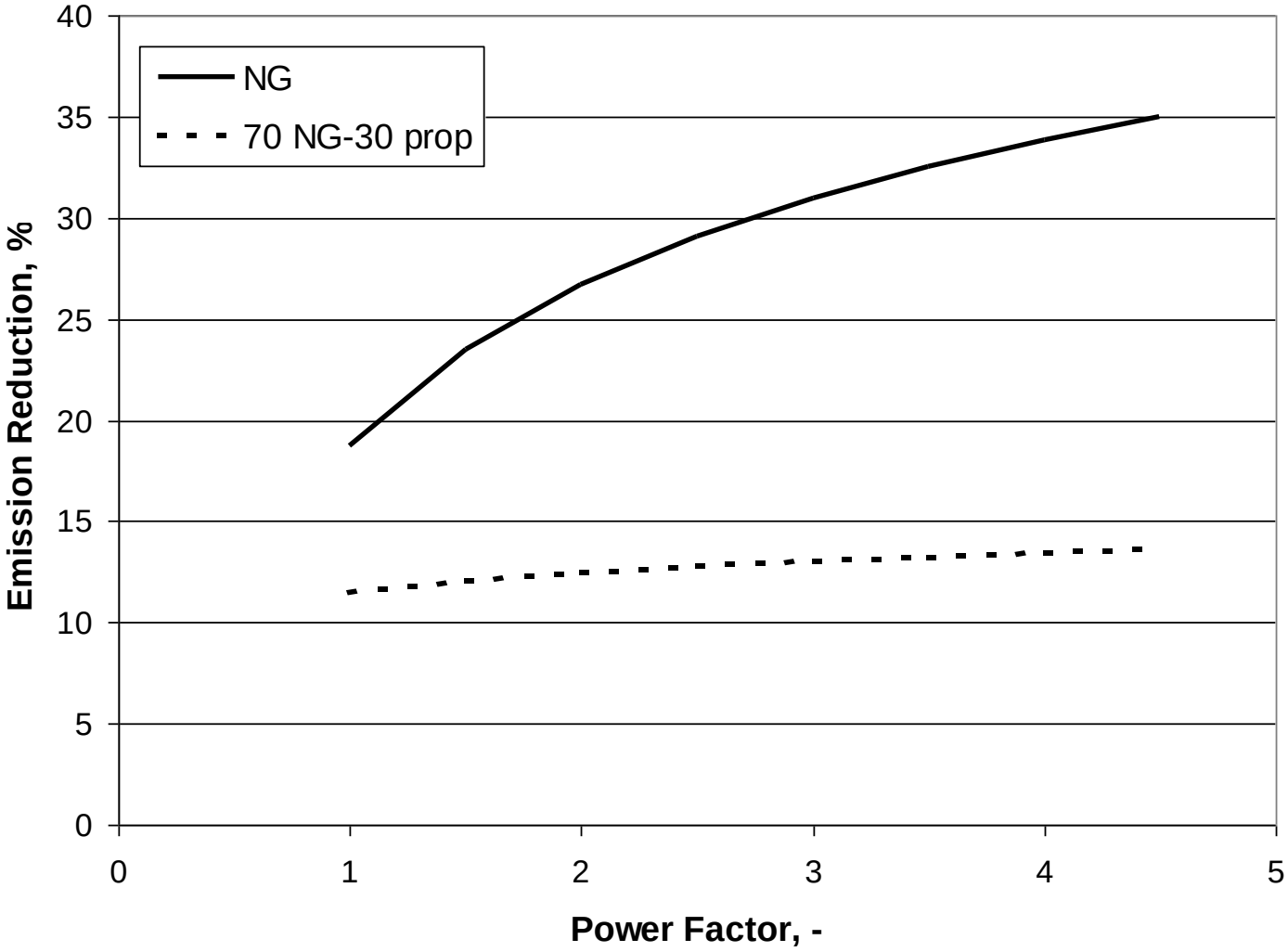
4” and 6” pipe, 10, 20 and 30 kg/h NG

Results with 30% propane in fuel



4” and 6” pipe, 10, 20 and 30 kg/h 70% NG, 30% propane

Emissions reduction from 10% to 35%



4” and 6” pipe, 10, 20 and 30 kg/h NG

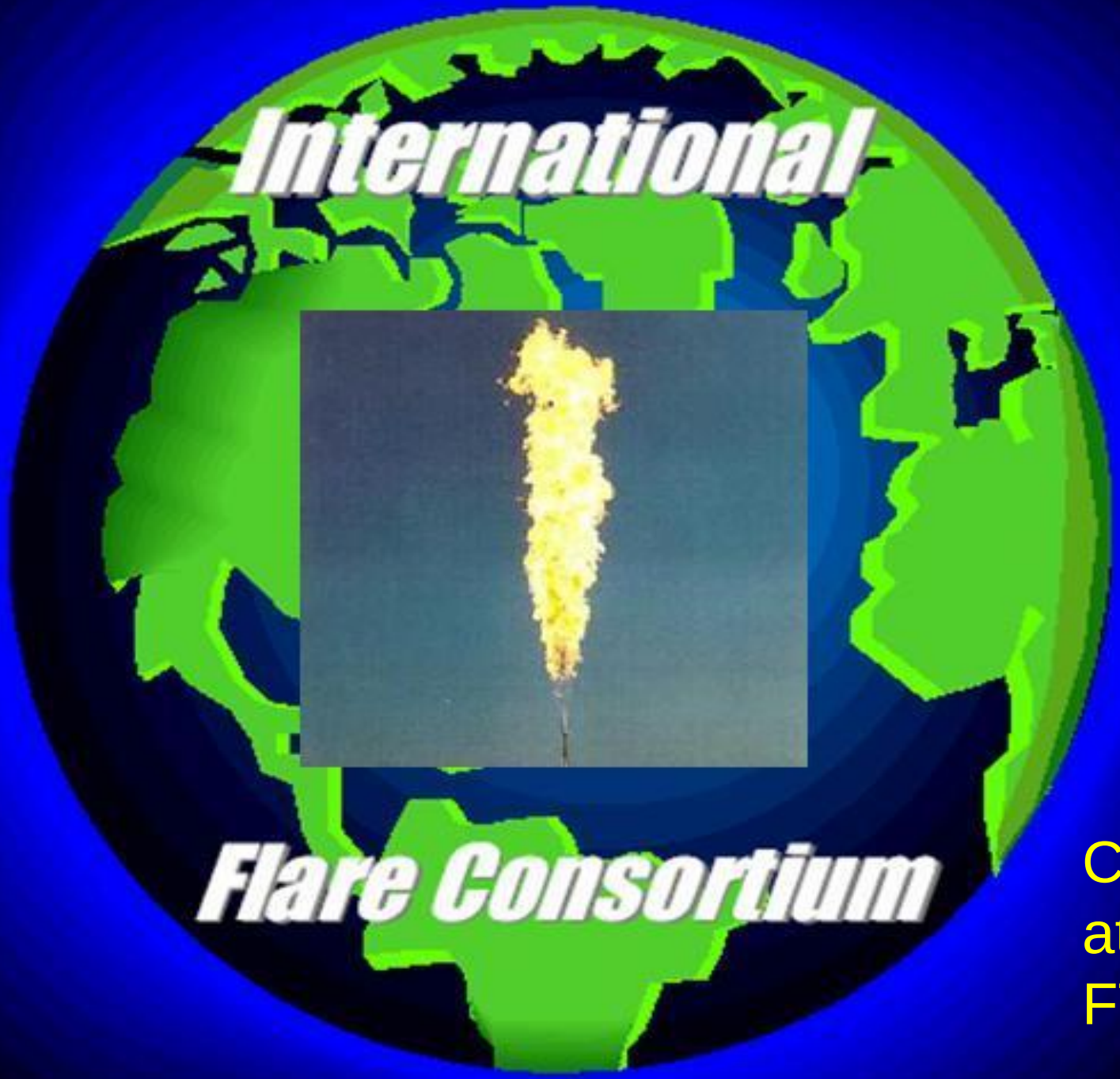
Future Work

- Need to evaluate new tip for stability at low wind speeds.
- Look for further improvements: goal to obtain better than 95% over full range of wind speed.
- Look for ‘best of breed’ for existing flare tips

Acknowledgements

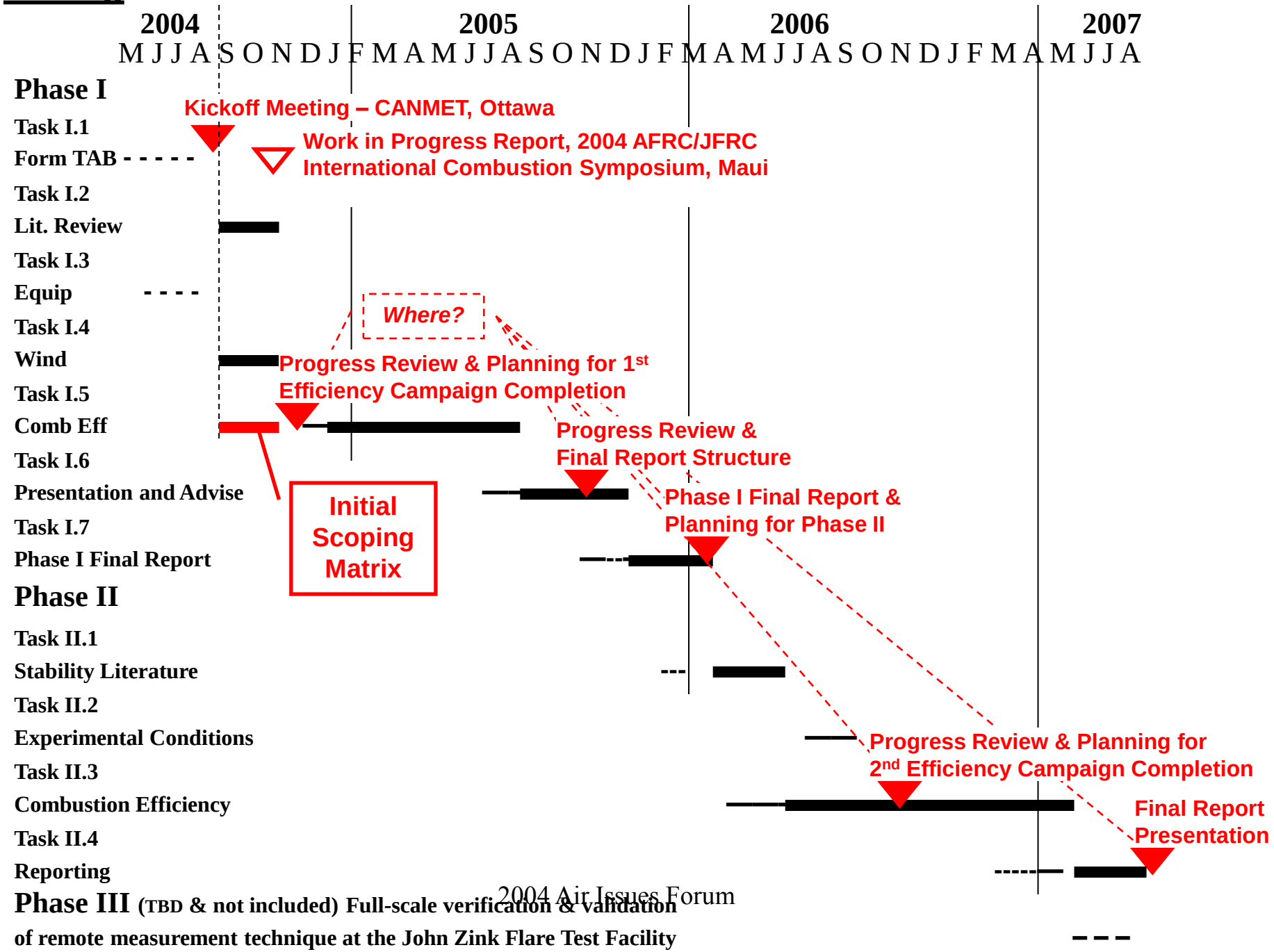
This work supported by NRCan and:

- ERAC project: Flare Burner Design.
- Climate Change Action Plan and PERD, under the auspices of Bill Reynen, Environment Canada.



Centred at the FTF

Timing:


2004
2005
2006
2007
M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A
Phase I
Task I.1
Form TAB
Kickoff Meeting – CANMET, Ottawa
Work in Progress Report, 2004 AFRC/JFRC
International Combustion Symposium, Maui
Task I.2
Lit. Review
Task I.3
Equip
Where?
Task I.4
Wind
Progress Review & Planning for 1st Efficiency Campaign Completion
Task I.5
Comb Eff
Progress Review & Final Report Structure
Task I.6
Presentation and Advise
Initial Scoping Matrix
Phase I Final Report & Planning for Phase II
Task I.7
Phase I Final Report
Phase II
Task II.1
Stability Literature
Task II.2
Experimental Conditions
Progress Review & Planning for 2nd Efficiency Campaign Completion
Task II.3
Combustion Efficiency
Final Report Presentation
Task II.4
Reporting
Phase III (TBD & not included) Full-scale verification & validation of remote measurement technique at the John Zink Flare Test Facility

Signed-On

ExxonMobil, Total, API, WSPA,
BP, John Zink

Needed:

Canadian Board Members

Contact Peter Gogolek