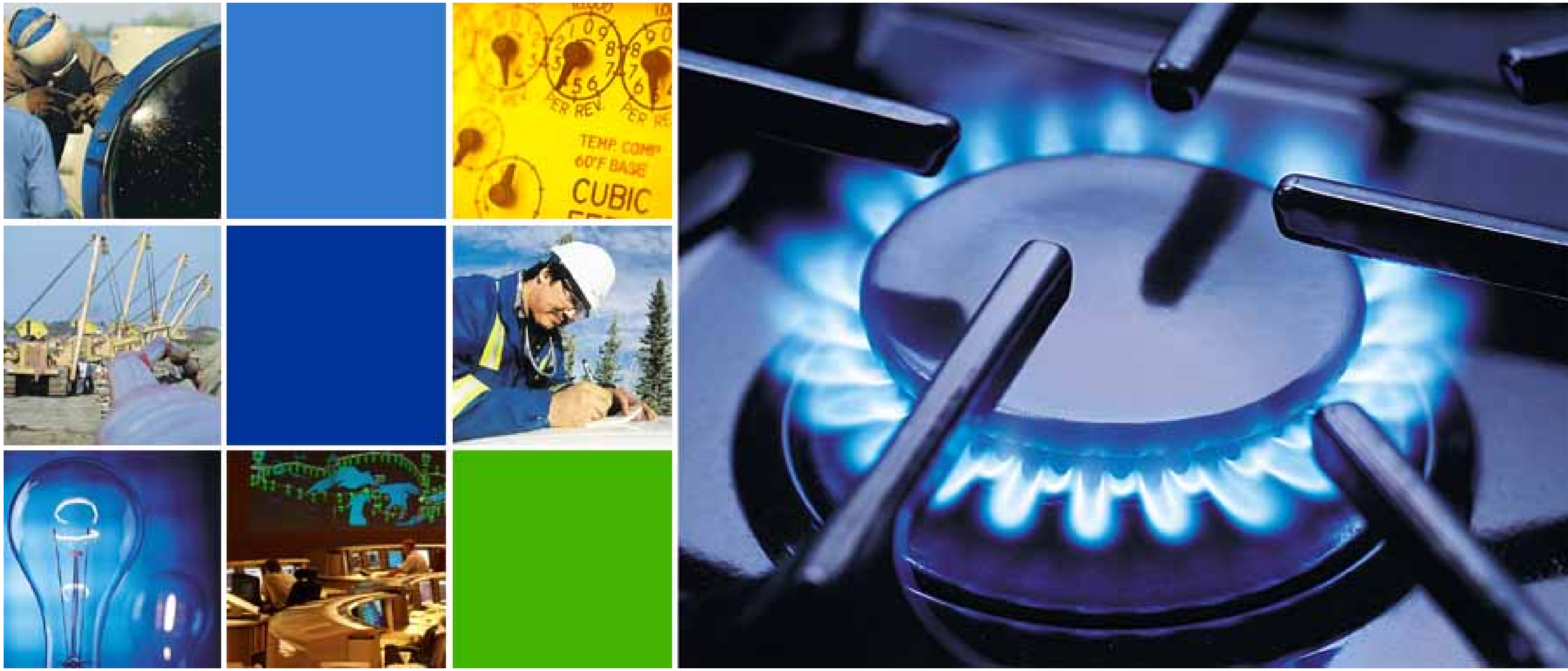
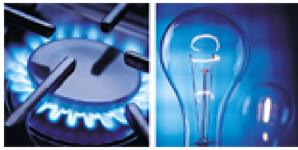


Usage of design factors above 72% SMYS in Canada

Brian Rothwell

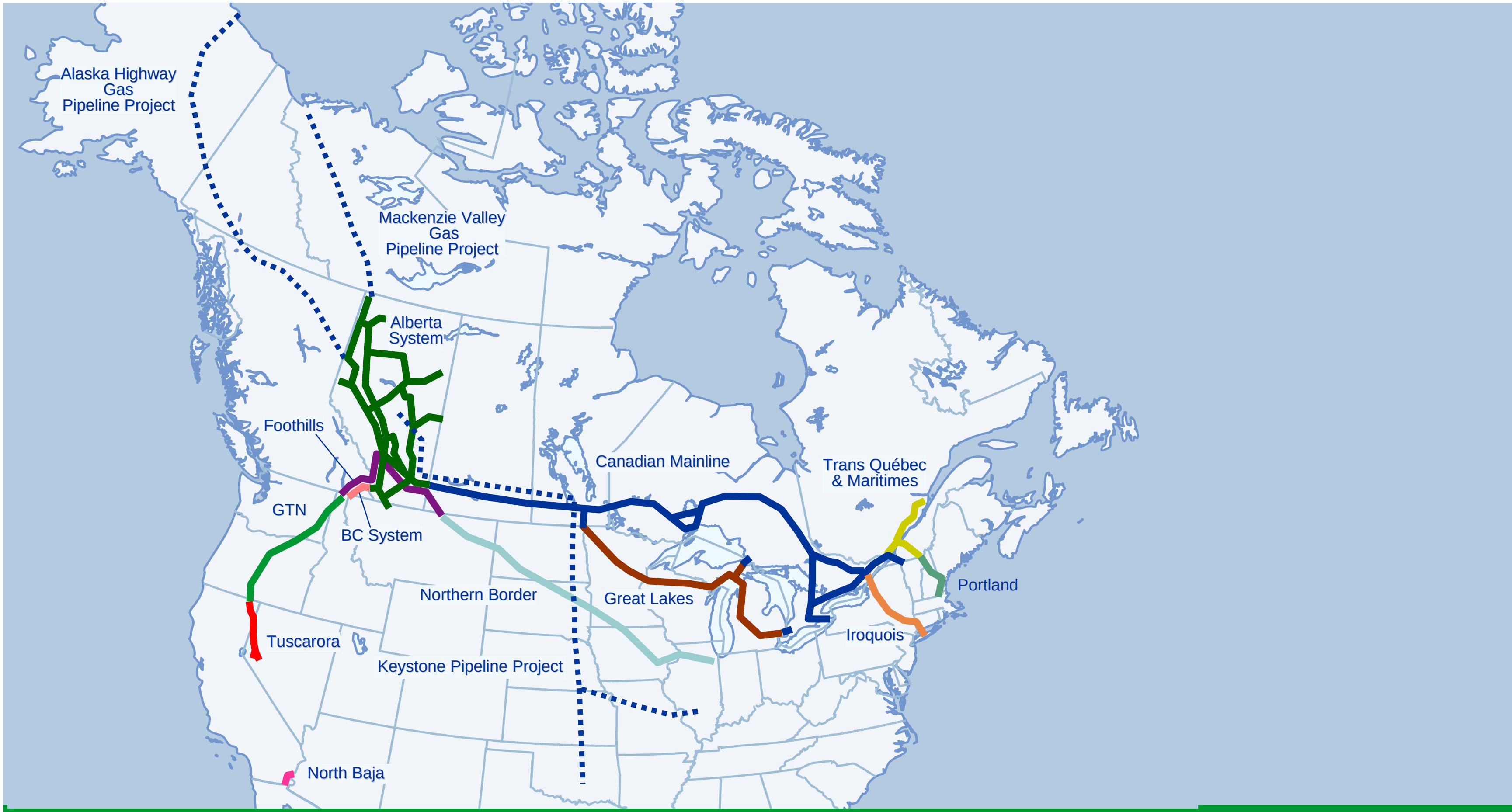
TransCanada
In business to deliver

Basis of presentation

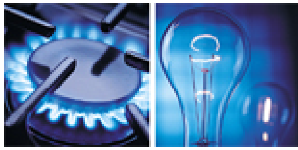


- Largely based on TransCanada experience operating a large gas transmission system
    - TransCanada owns and operates about 40% of the total length of (gas and liquid) transportation pipelines in Canada
    - Liquid pipelines have used design factors over 0.72 for new construction in the last decade, but the accumulated operating experience is much less

TransCanada's Natural Gas Transmission Assets



41,000 km of wholly owned pipeline; 11.5 Bcf/day



Outline of presentation

- Historical background to use of higher design factors in Canada
- Operating experience on the TransCanada system
  - Range of pipeline attributes covered
  - Incident statistics and comparison with other jurisdictions
- Some potential effects of design factor/hoop stress on pipeline integrity
- Design factors >0.72 in other countries
- General conclusions

Early history

- Work on basing MAOP on hydrostatic test pressure completed by Battelle in the late Sixties
- Indicated that it was the margin between test pressure and MAOP that was most significant in ensuring operating integrity
- In the early Seventies, TransCanada and Alberta Gas Trunk Line and their regulators agreed to a regime that allowed pipelines to be operated at up to 80% of hydrostatic test pressure
- Pipelines were upgraded by pressure testing, and testing of new and existing pipelines to a minimum pressure corresponding to 100% SMYS allowed operation up to 80% SMYS

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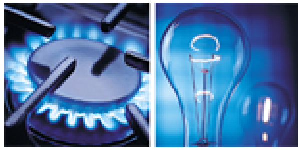
History – Canadian pipeline standards



- CSA Z184-M1973 (gas pipelines) permitted operation at up to 80% SMYS, based on hydrostatic testing at a minimum of 1.25 times the intended MAOP.
  - For several editions, there was a slightly anomalous situation of parallel “hydrostatic test factors” and design factors; MAOP could be higher than design pressure.
  - In 1990 (for oil) and 1992 (for gas) this anomaly was removed by the adoption of a single design factor of 0.80, and location factors that varied from 1.000 to 0.550 for class locations 1 to 4, respectively.
- Since 1994, this approach has been maintained in CSA Z662, the current standard for oil and gas pipeline systems

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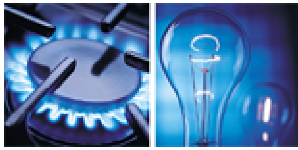
TransCanada's service experience



- On the Alberta system, there are about 9600 km of pipelines with MAOP corresponding to 78% or more of SMYS, ranging from 150 to 1219 mm OD, 359 to 690 MPa SMYS, installed (or upgraded) between the early Seventies and 2005.
- On the Mainline system (East of Alberta-Saskatchewan border) there are about 7200 km of pipelines with MAOP corresponding to 77% or more of SMYS, ranging from 508 to 1219 mm OD, 359 to 550 MPa SMYS, installed (or upgraded) between the early Seventies and 2005.
- The Foothills Pipe Lines system consists of over 1000 km of 914 and 1067 mm OD, 448 to 483 MPa SMYS pipelines with MAOP corresponding to 80% SMYS, installed between 1979 and 1998.

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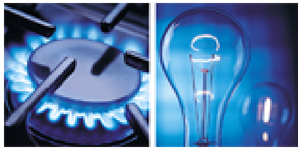
Performance data



- I’ll start by saying that it’s amazingly difficult to get accurate performance data in the form of incident frequencies, broken down by such attributes as hoop stress or pipe size or grade.
  - For the most part, I have to use broad categories like design/construction epoch to infer the effects of variables such as coating type, material specifications, **stress level**...
- Concentrate on rupture frequency, since the major component of risk for a gas transmission system arises from ruptures
  - We have had very few large leaks (e.g. direct punctures) in the history of the system – unlike Europe (about 1/3 of all incidents, mainly EI)

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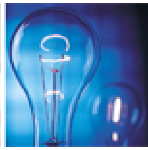
Overall gas release incident frequency (leaks and ruptures)

- TransCanada – 0.20 per 1000 km yr (over 1 million km yr since 1954)
- EGIG – 0.41 per 1000 km yr (2.8 M km yr 1970-2004)
  - 0.17 per 1000 km yr (0.57 M km yr 2000-2004)
- US DOT - 0.14 per 1000 km yr (~7.3 M km year between 1985-2000 – onshore transmission only)
  - Leaks under-represented in DOT database ($50K cut-off)
  - All sources show declining frequency over the most recent periods analysed (factor of 2 or more on overall)
  - No evidence here for an effect of design factor on failure frequency – recall nearly 45% of our system is operating close to 80% SMYS, very little of US or EGIG database

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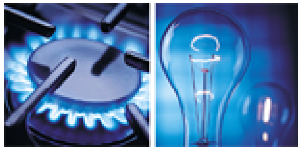
Rupture frequency



- Overall lifetime rupture frequency for TransCanada is 0.07 per 1000 km yr
  - A little higher than EGIG (~0.06 per 1000 km yr)
  - Has declined from an early peak connected with the small exposure and a blip in the 70s (*not* connected with upgrades but with material and construction quality management issues)
- Rolling five-year mean is currently around 0.05 per 100 km yr
- Comparable with EGIG; average system age is older.

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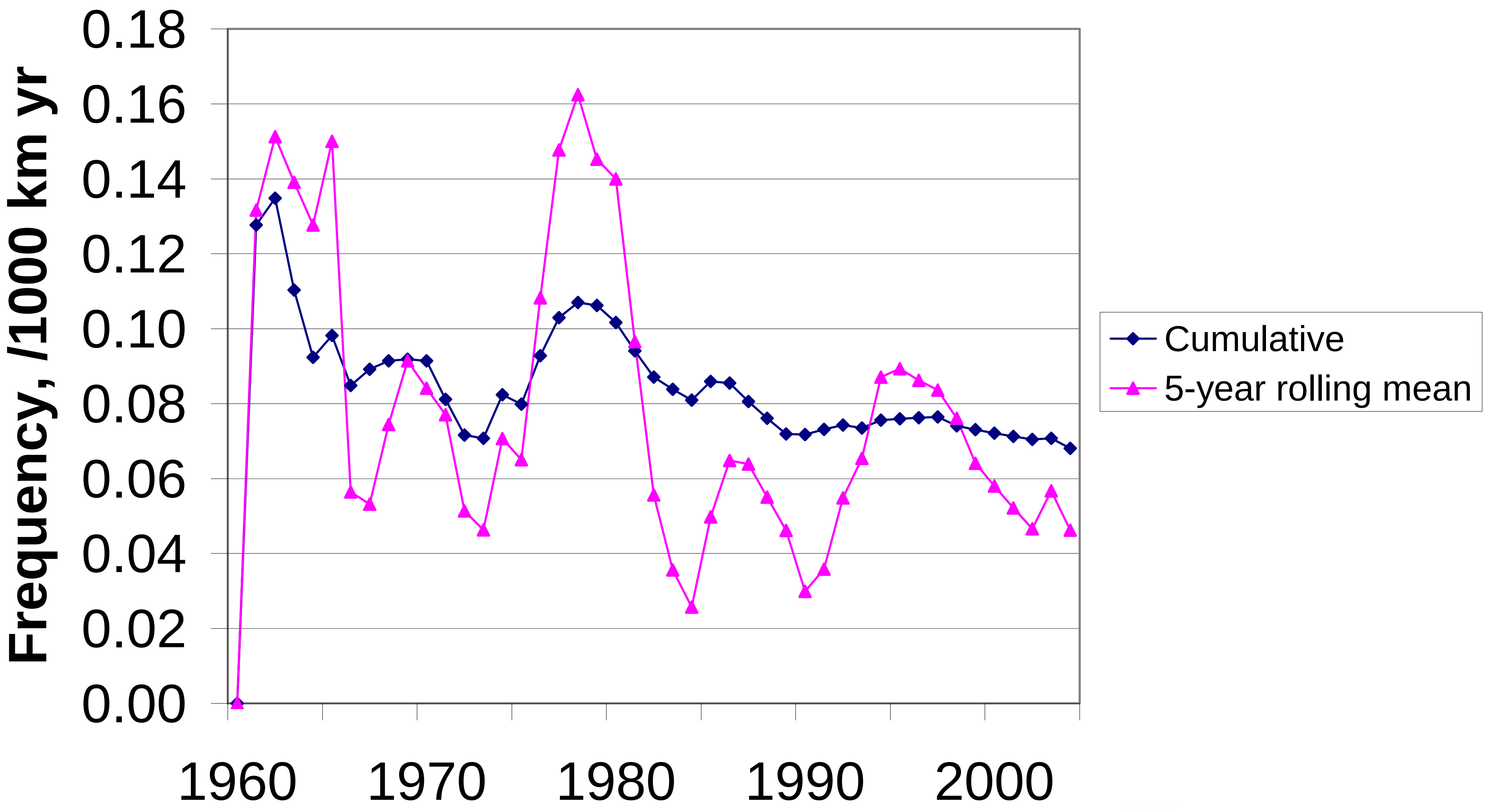
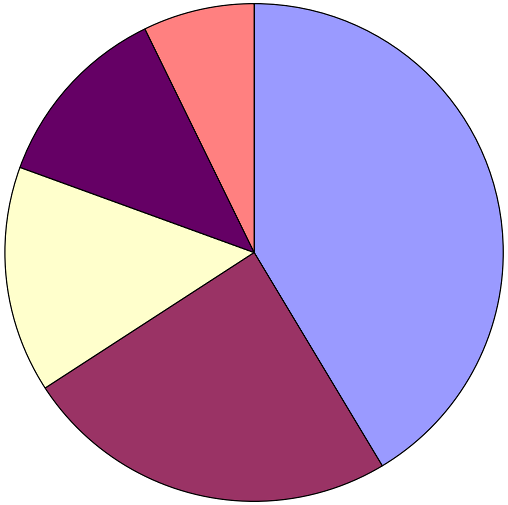
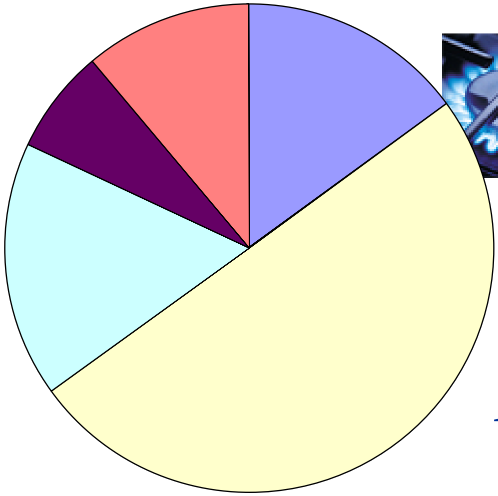
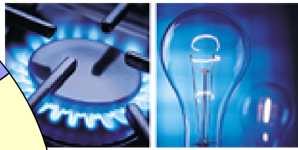
Rupture frequency





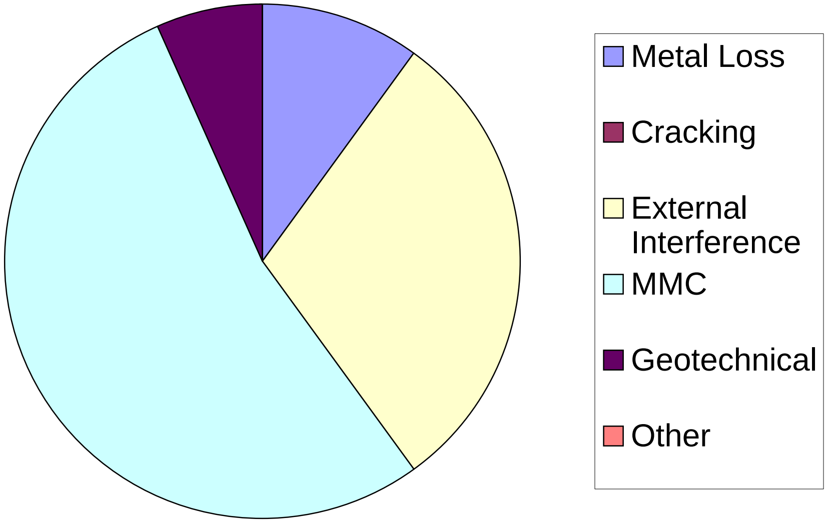
TC ruptures “late epoch”



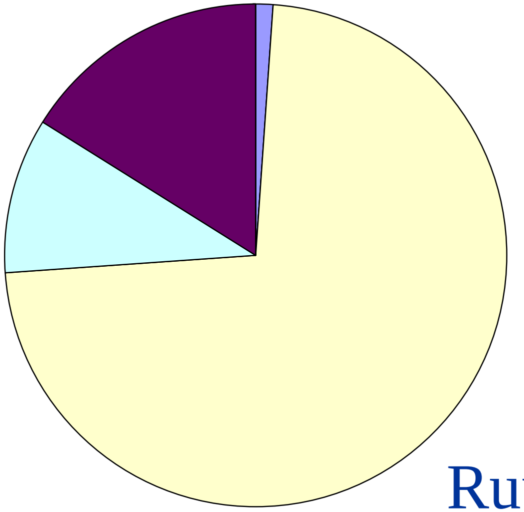


All

EGIG 1970-2002



TC ruptures “early epoch”



Ruptures

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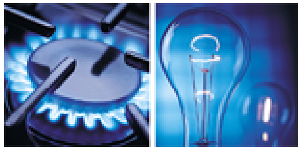
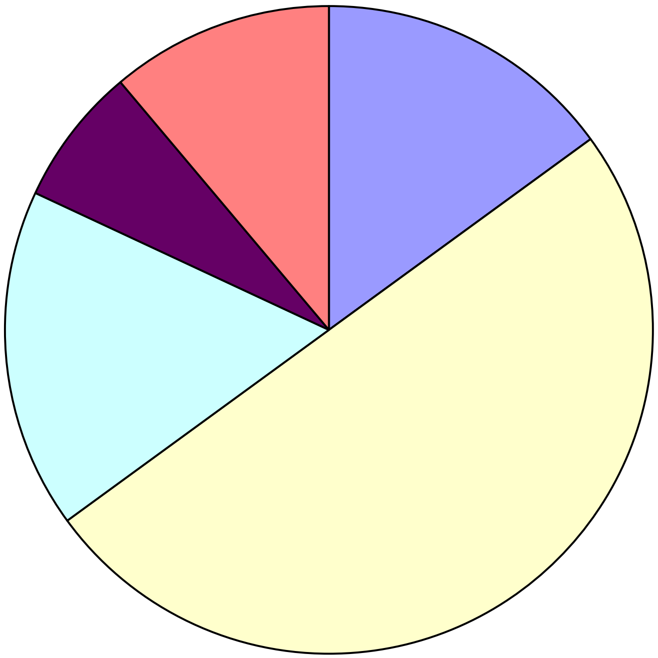
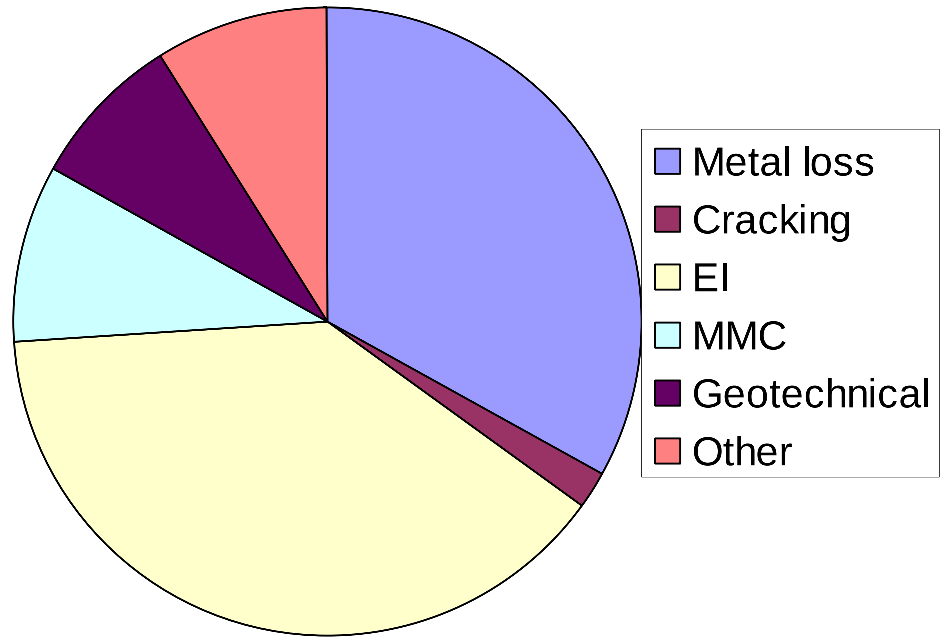


EGIG incident causes



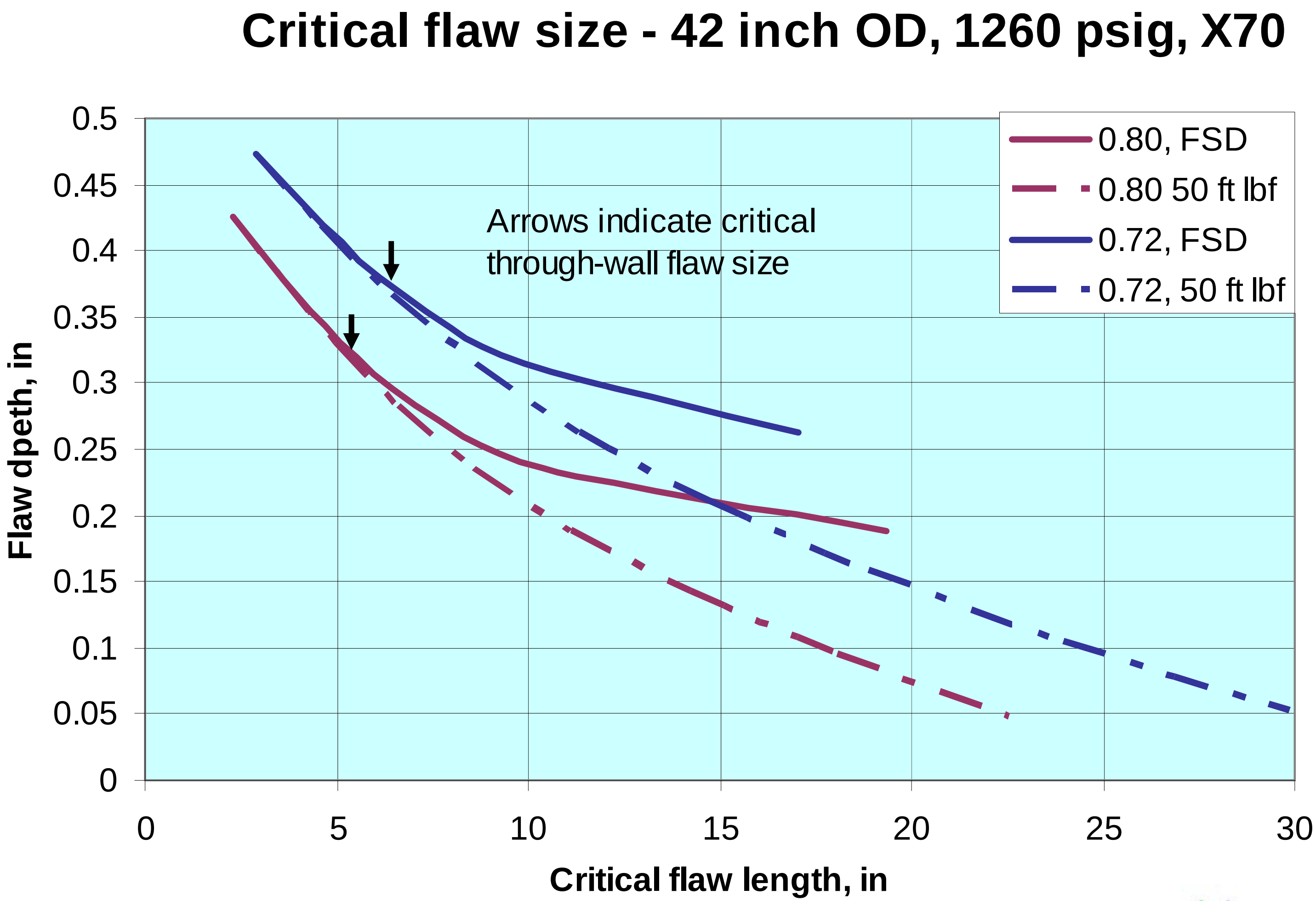
DOT incident causes



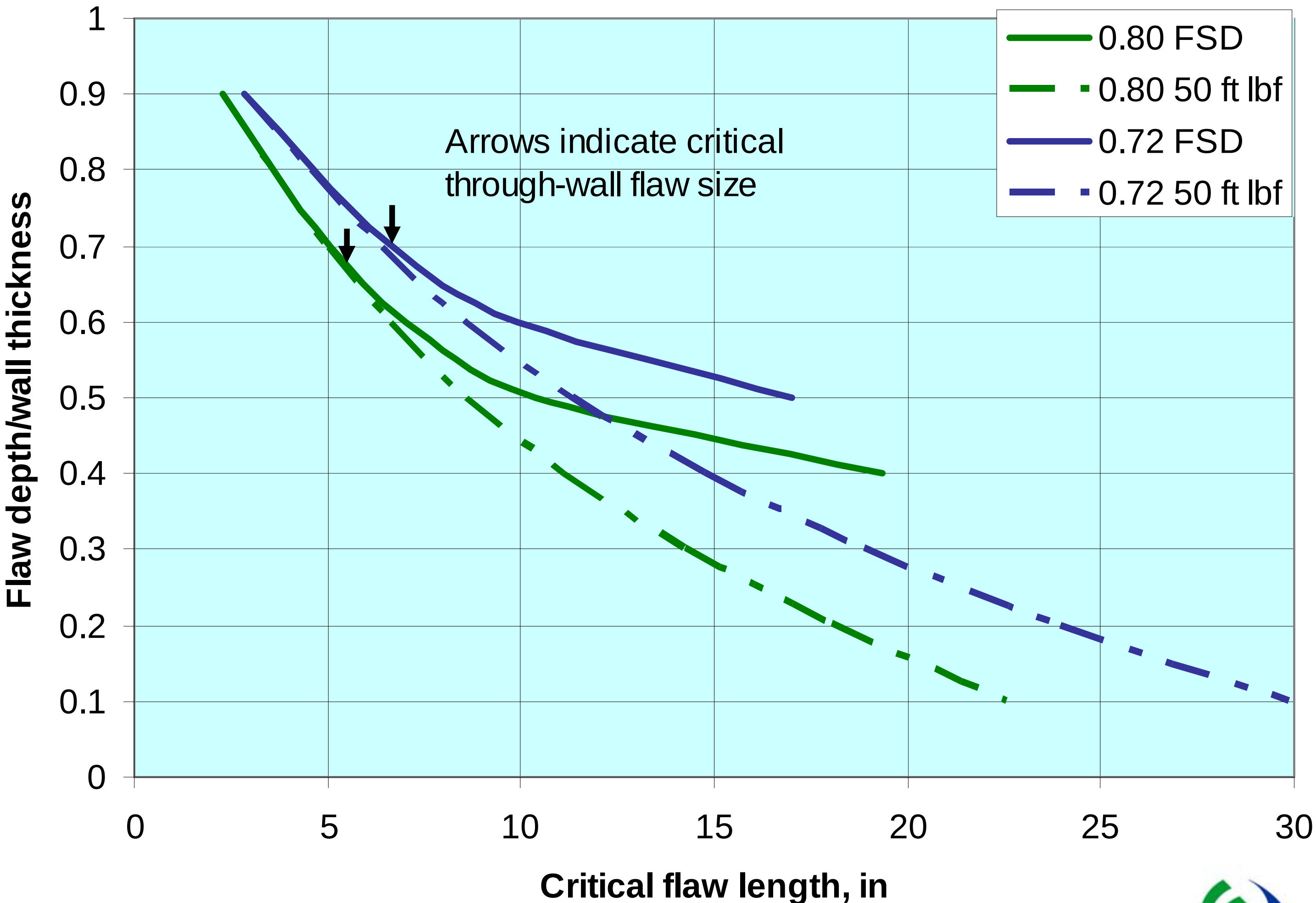
Direct effects of design factor on failure conditions

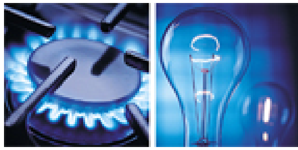
- Obviously, higher design factor can have some influence on failure e.g.
  - Reduction in wall thickness reduces critical defect size
  - All else being equal, reduces puncture resistance
- For Canadian conditions, there has been no clear link to the initiation or growth of SCC (predominantly near neutral) – conclusions of NEB enquiry 1996
  - No useful threshold stress
  - SCC has been controlled by integrity management efforts without long-term change in MOP

Critical flaw size

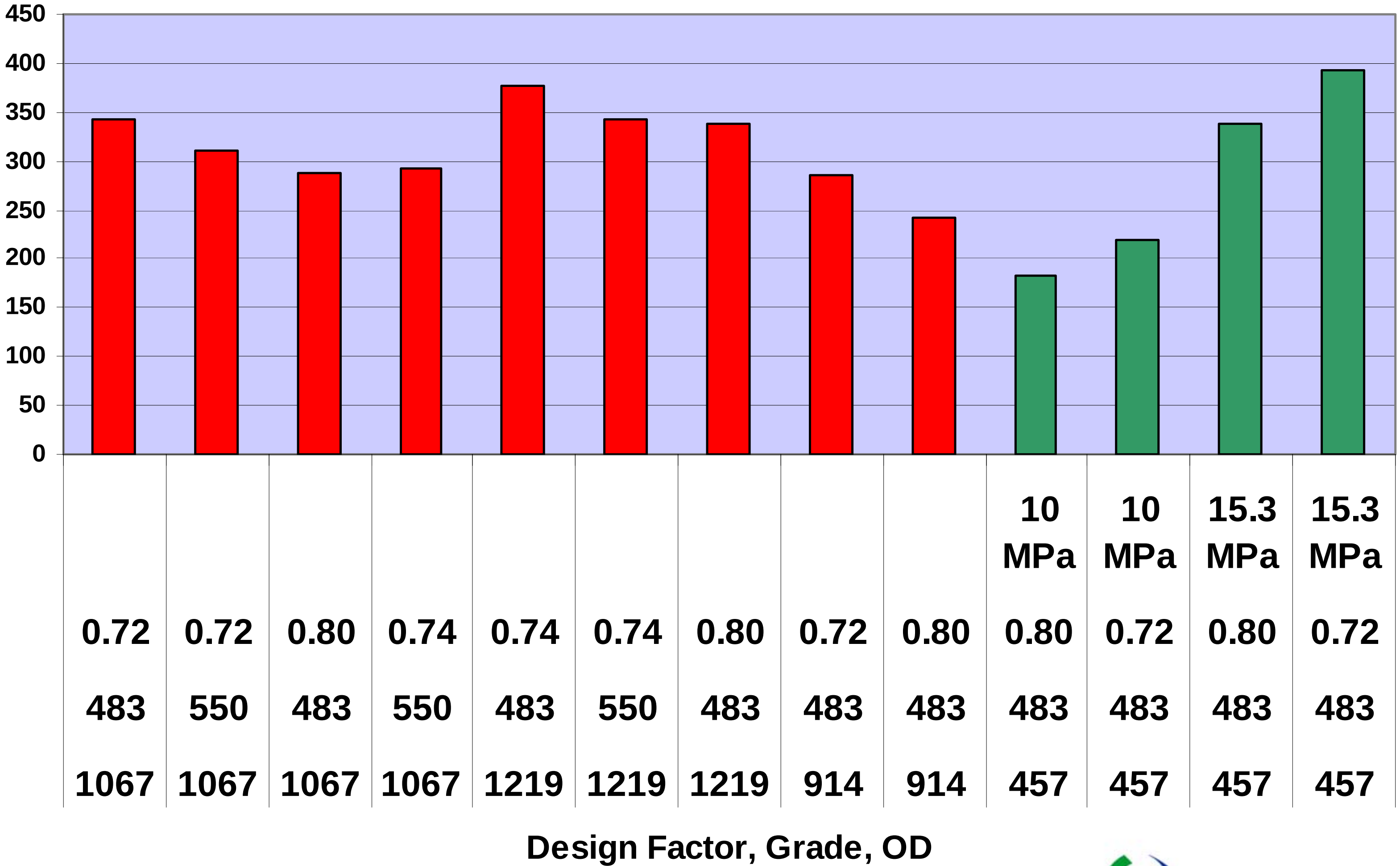


Critical flaw size – 42 in OD, 1260 psig, X70

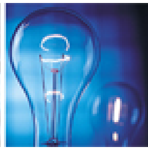




Deterministic puncture resistance (lower bound), kN
MOP 7 MPa except as noted



Use of design factors >0.72 in other countries



- **I don’t need to say much here**
  - **“Grandfathered” lines in the USA**
    - Bob Eiber presentation
  - **Australia**
    - Originally 2(?) lines at ~0.80– AS2885.1 later restricted DF to 0.72
    - New edition proposes to restore maximum DF to 0.80
  - **Mozambique to Secunda**
    - Use of B31.8 Class 1 Division 1 – 865 km pipeline
    - Don’t know much detail
  - **Transco (UK) uprating exercise**
    - Up to 0.80, (~0.73) based on structural reliability analysis
    - Advantica presentation

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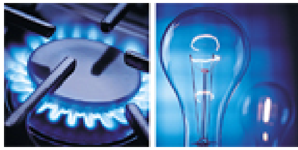
General conclusions



- There is a large amount of experience with gas pipelines operating at pressures corresponding to design factors (based on OD and nominal wall) close to 0.80
- There is no evidence that the integrity performance of such pipelines is inferior to that of lines operated at 0.72 or lower
  - In fact, it has been better, but this is largely related to better technology in materials, construction, operation and maintenance starting in the late Seventies
- Actual historical integrity performance has not been determined by internal pressure design factor, but by improved quality and integrity management processes that appropriately address all threats
- These vital aspects are at the core of most national and international pipeline standards today.

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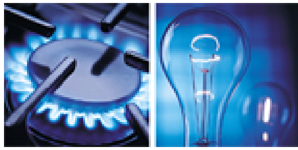

The End