POLITECNICO DI MILANO

Impact of Gas Phase Impurities on CO_2 Compression

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WHY IMPURITIES IN CO_2 STREAMS?

ASSUMPTION

CO_2 capture and storage is one of the most acceptable solutions to reduce the emission of greenhouse gases into the atmosphere

In real power plants, technical and economical reasons bring about that CO_2 streams captured are often impure, meaning that they can also include significant fractions of species such as Ar, N_2, O_2, SO_2, H_2S or others.

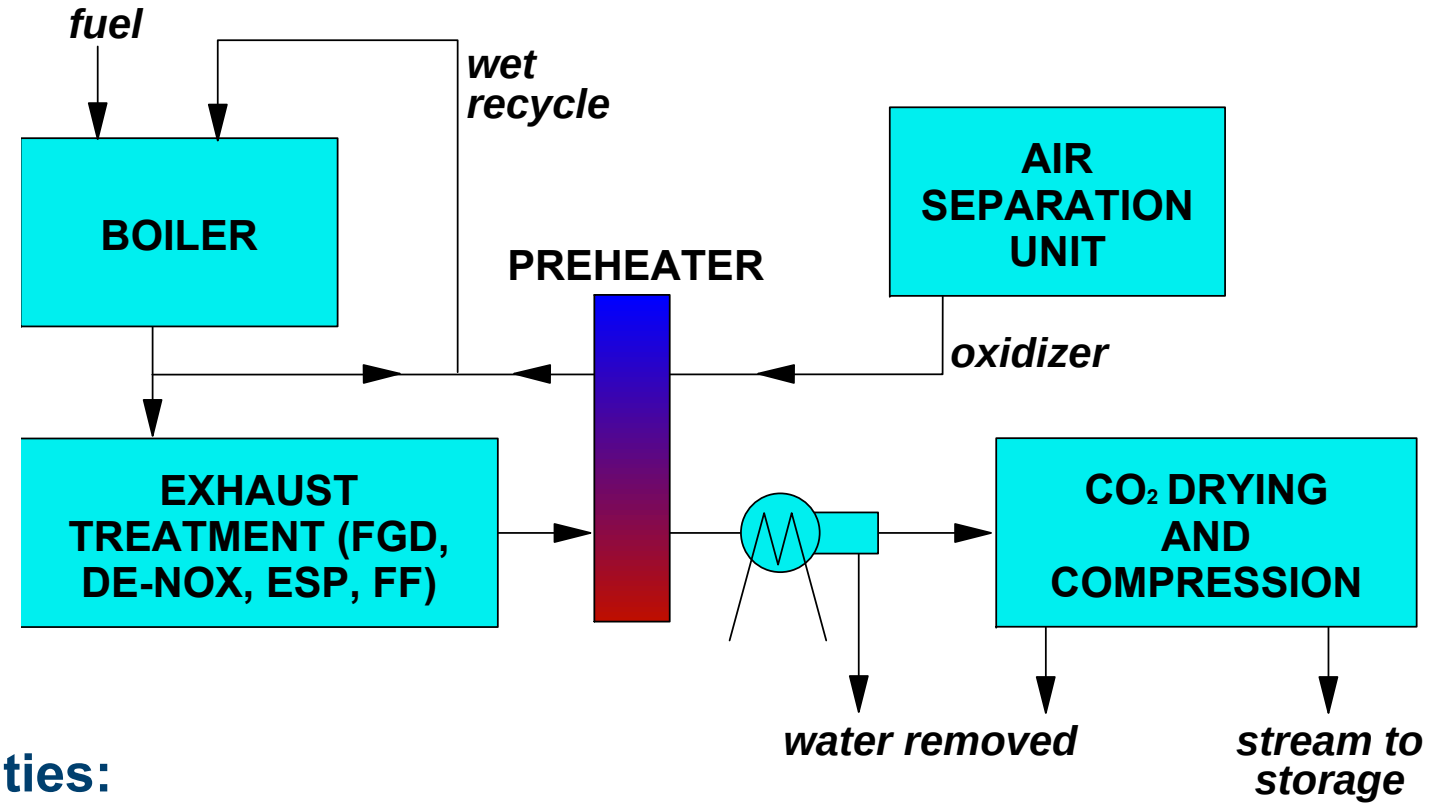
Types and concentration of the impurities are essentially dependent on fuel and capture technique adopted

CO_2 CAPTURE ALTERNATIVES

CO_2 capture in a power cycle eventually falls in one of the following three categories:

- CO_2 separation from flue gases (post-combustion capture)
  → high level of purity is expected
- CO_2 separation from synthesis gas subsequent to CO conversion (pre-combustion capture)
  → co-sequestration of CO_2 and H_2S may be economically profitable
- CO_2 concentration in the exhaust gas (e.g. oxyfuel combustion)
  → significant presence of contaminants in the CO_2

OXYFUEL COMBUSTION



Impurities:

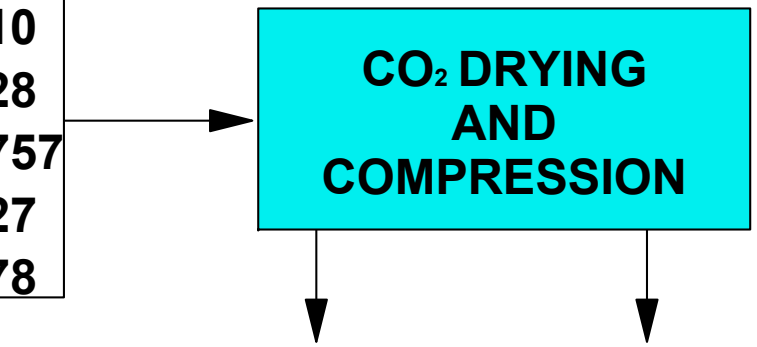
- O_2 due to oxidizer excess required for complete combustion
- N_2, Ar carried with O_2 stream (concentration dependent on O_2 excess and purity)
- H_2O, SO_X, NO_X due to oxidation of species contained in the fuel (concentration dependent on the exhaust treatment)

EXHAUST COMPOSITION

Assumptions:

- Illinois #6 coal
- 95% O_2 purity (Ar = 3.65%, N_2 = 1.35%)
- 15% oxidizer excess (3.3% O_2 concentration at boiler exit)
- 65% recycle fraction (2121 °C adiabatic combustion temperature)
- complete removal of SO_X and NO_X

		mol %
T = 35 °C	H_2O:	5.910
p = 1.05 bar	Ar:	4.028
	CO_2:	83.757
	N_2:	1.827
	O_2:	4.478



water removed

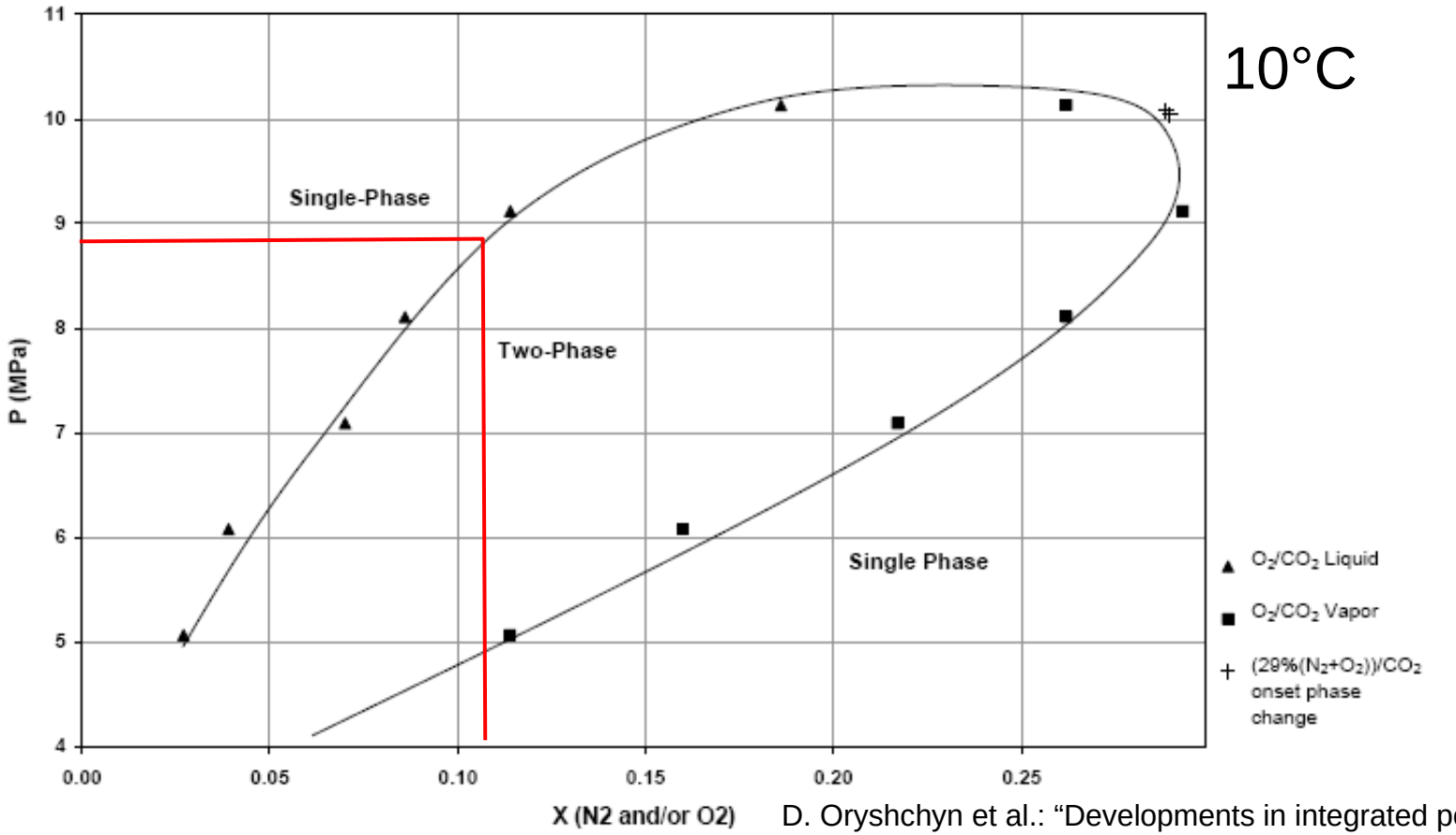
stream to storage

	mol %
H_2O:	------
Ar:	4.281
CO_2:	89.018
N_2:	1.942
O_2:	4.759

VAPOR-LIQUID EQUILIBRIUM

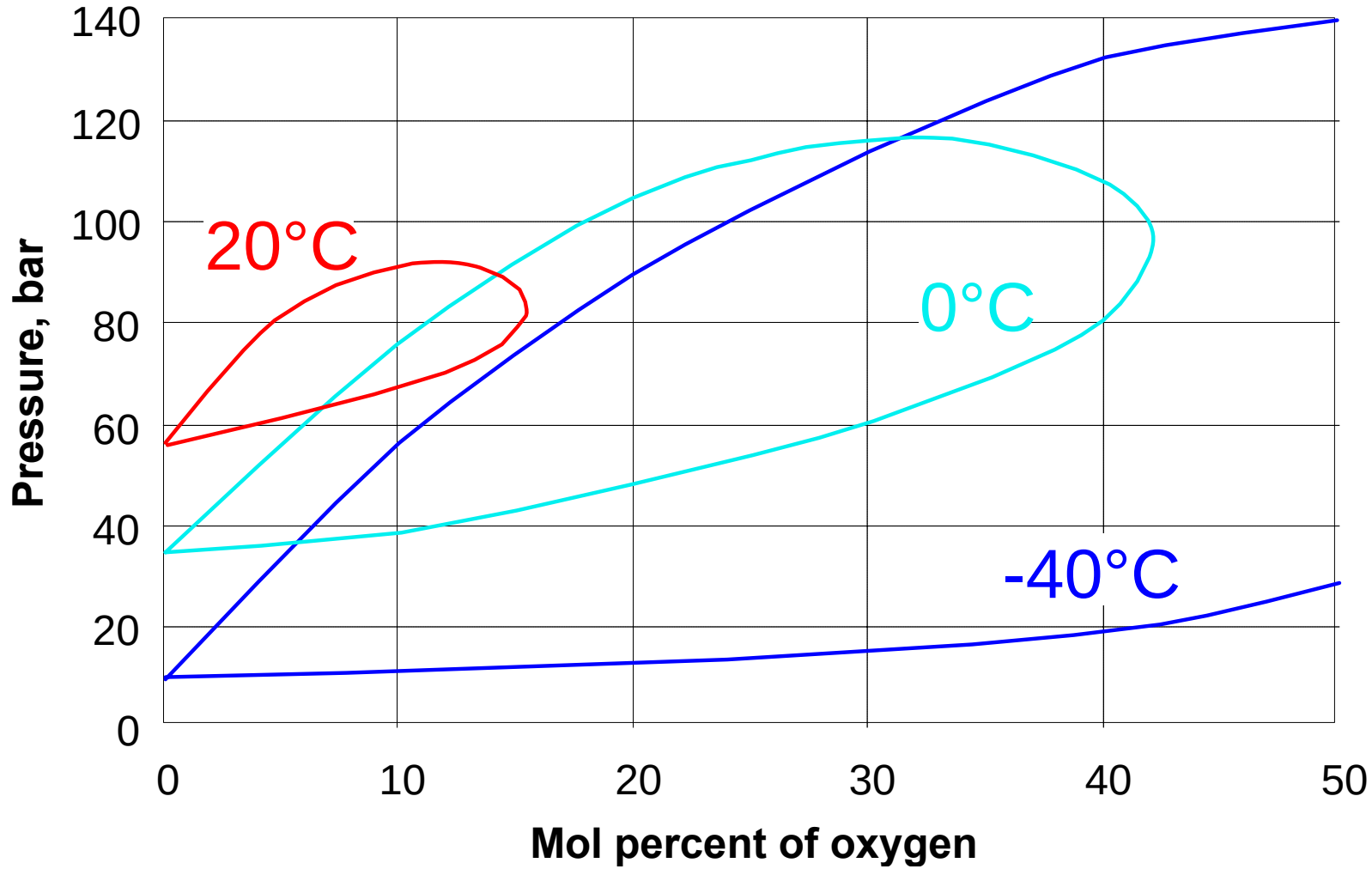
The question arising is: can such a mixture be compressed in dense, single phase for transport and well injection?

Looking at data available in the literature, the answer is YES



D. Oryshchyn et al.: "Developments in integrated pollutant removal for low-emission oxy-fuel combustion", 2006

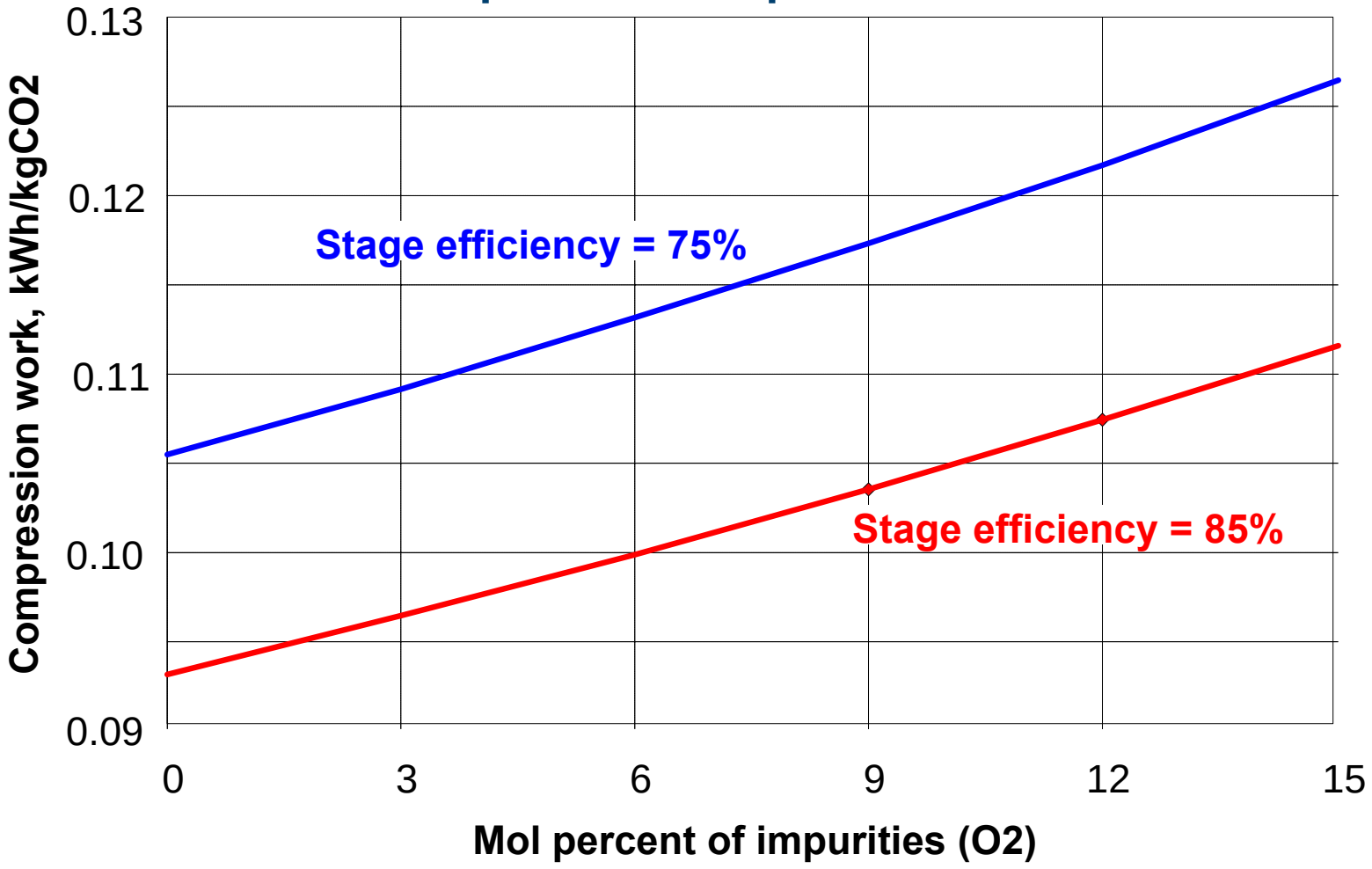
As temperature increases the two-phase area reduces



G.H Zenner, L.I. Dana: “Liquid-vapor equilibrium compositions of carbon dioxide-oxygen-nitrogen mixtures”, 1963

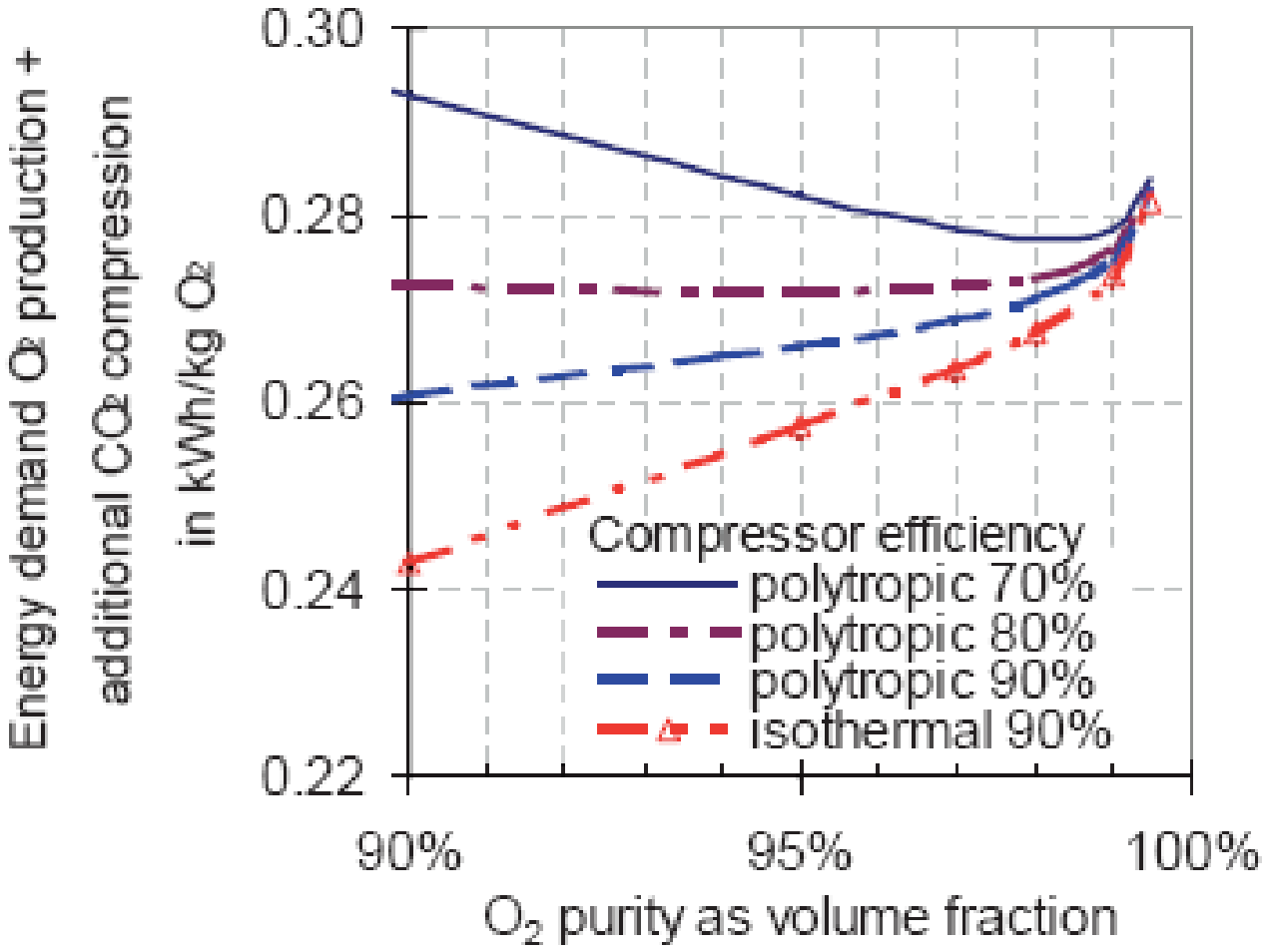
EFFECT OF IMPURITIES ON COMPRESSION POWER

Assumptions: 5 stages intercooled compression from 1.05 to 100 bar
Intercooler outlet temperature: 35°C
Intercooler pressure drop: 2%



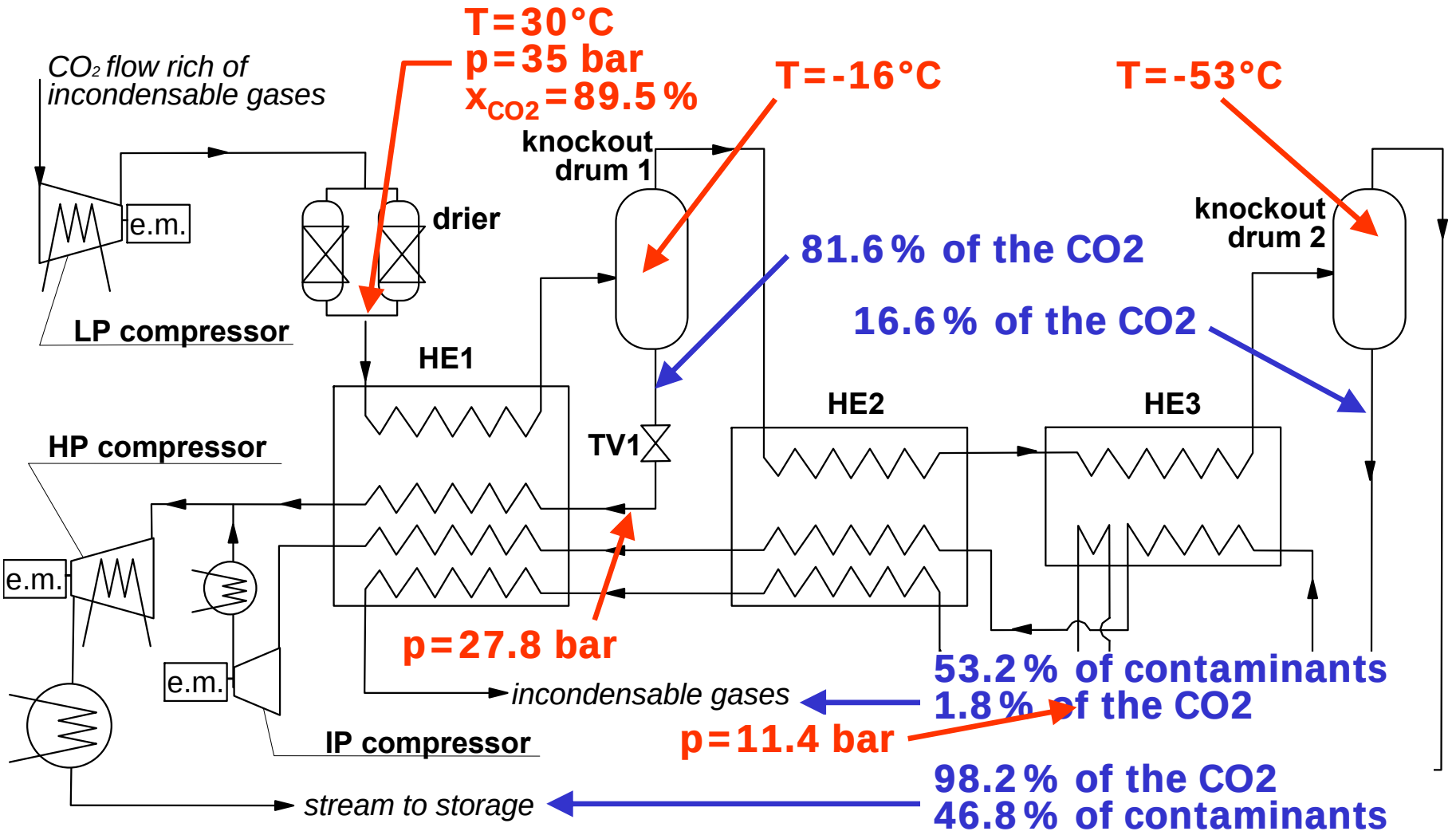
INFLUENCE OF OXYGEN PURITY

How does oxygen purity affect the CO_2 compression power?



G. Göttlicher. "The Energetics of Carbon Dioxide Capture in Power Plants", 2004

SEPARATION OF IMPURITIES



After Wilkinson M. B. et al.: "CO2 Capture via Oxyfuel Firing: Optimization of a Retrofit Design Concept for a Refinery Power Station Boiler", 2001 and Pelliccia G.: PhD thesis, Politecnico di Milano, 2004

POWER REQUIREMENTS FOR SEPARATION

- The power required for contaminants separation is the effect of the additional compression work because of the pressure drop due to the liquid streams throttling
- The power increase is independent of the compression overall pressure ratio
- The pressure drop in the throttling valves brings about a ~10% power increase for a compression from 1.05 to 100 bar. More relevant percentage increases are expected for CO_2 streams available at higher pressure

CONCLUSIONS

- The CO_2 impurities, in the expected concentration, do not compromise the possibility to obtain a single, dense phase, high pressure stream even if compression requires an extra power absorption compared to pure CO_2
- Impurities can be removed at the cost of limited CO_2 loss and power requirements
- More research activities are required to properly describe the behavior of multi-components mixtures
- Interest for these mixtures is not restricted to CO_2 compression but involves other steps of the CO_2 capture and storage process:
  - transportation (design and operation of long transport pipes)
  - well injection
  - migration in the geological formations of the storage fields

THERMOPHYSICAL PROPERTIES OF CO_2 MIXTURES

Politecnico di Milano is launching an experimental activity regarding two-phases equilibria of CO_2 rich mixtures.

Object of this activity is to acquire the sets of experimental data necessary to calibrate the mathematical models used to predict the thermodynamic properties of CO_2 rich mixtures. In particular:

- acquisition of p, v, T conditions for mixtures of known composition
- definition of mixing coefficients for binary mixtures
- definition mutual interaction coefficients for multi-component mixtures

An experimental equipment based on a vibrating tube densimeter is under construction in our laboratory

Investigations centered on conditions where CO_2 shows strong real gas effects:

- pressure range up to 300 bar
- temperature range from ambient to 150°C (possible extension to cryogenic temperatures with additional equipments)

SCHEMATICS OF THE TEST DEVICE