Chapter 1.7: Transport properties

- The properties so far considered were for thermal changes of steam;
- Transport properties are of use for working out the flow behaviour;
- These are:
  - density,
  - Viscosity,
  - Prandtl number (to be met in convective heat transfer,
  - thermal conductivity;
- They set the heat and mass transfer characteristics;
- There are other electrical properties and optical properties, but they are not of relevance to this course.

Density

- Density is affected by temperature and pressure
- We know perfect gases have the equation of state
- In the case of steam, the steam tables tell us the density because it is not a perfect gas
- Likewise for refrigerant R134a
- See the video for the dense gas carbon hexafluoride

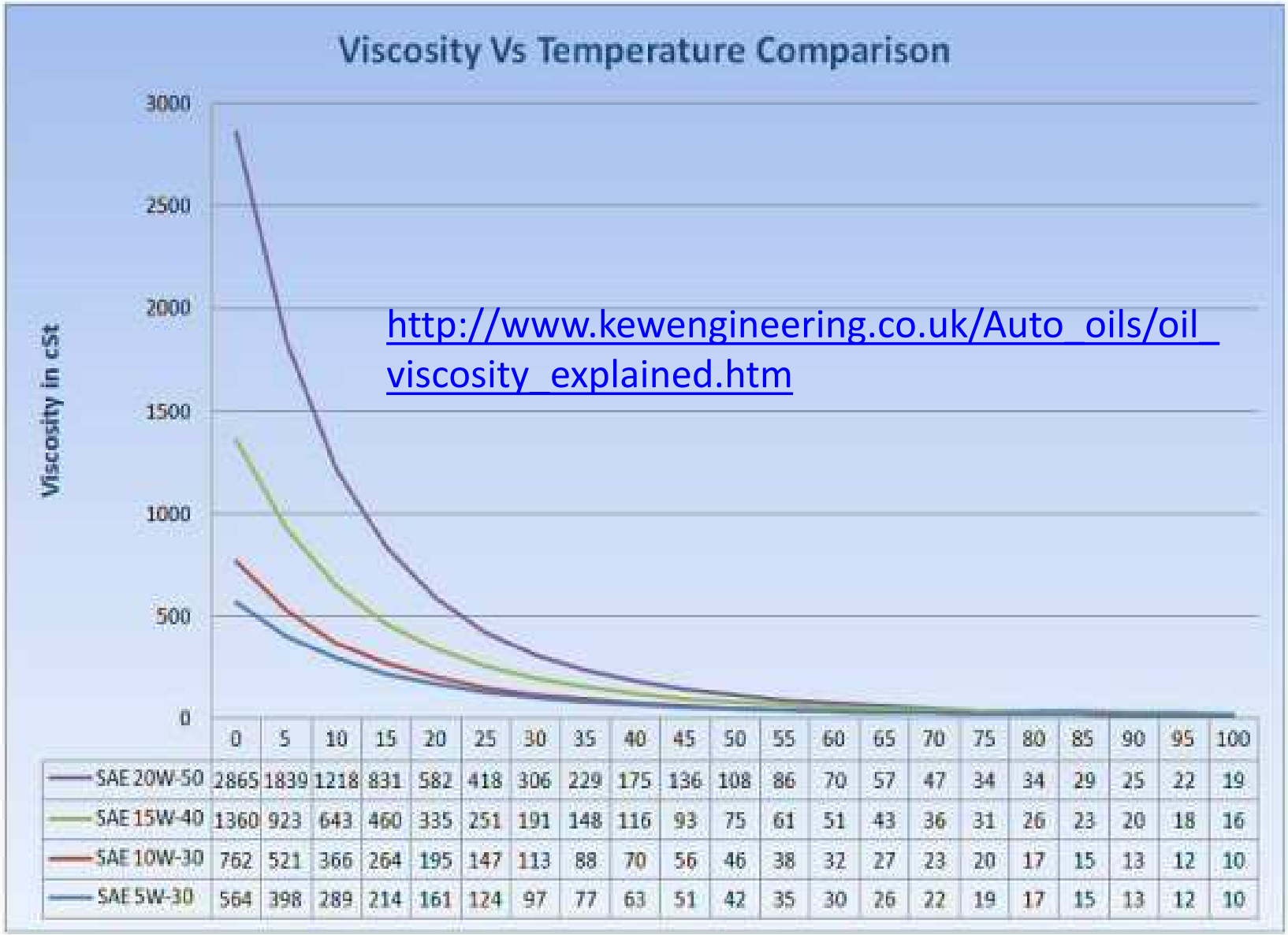
https://www.youtube.com/watch?v=DzLX96VWTkc&feature=youtu.be

Viscosity

- Viscosity in all fluids varies with temperature
- On page 10 of the tables there is viscosity of steam and water liquid stated in dynamic form (i.e. as a mass related figure), μ [$kg \cdot m^{-1}s^{-1}$]
- The specific volume [$m^3 \cdot kg^{-1}$] also on p.10 for steam can be used to invert and get density
- Density can be divided into dynamic viscosity to get kinematic viscosity (i.e. a measure of diffusiveness of the fluid), ν [$m^2 \cdot s^{-1}$]

Engine oil, viscosity

- An interesting case is engine oil (not in our tables), from https://www.youtube.com/watch?v=V5a4kP-5Jiw



	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
SAE 20W-50	2865	1839	1218	831	582	418	306	229	175	136	108	86	70	57	47	34	34	29	25	22	19
SAE 15W-40	1360	923	643	460	335	251	191	148	116	93	75	61	51	43	36	31	26	23	20	18	16
SAE 10W-30	762	521	366	264	195	147	113	88	70	56	46	38	32	27	23	20	17	15	13	12	10
SAE 5W-30	564	398	289	214	161	124	97	77	63	51	42	35	30	26	22	19	17	15	13	12	10

Thermal conductivity, k [W/mK]

- Just as there are solids which have varying levels of thermal conductivity [$W \cdot m^{-1}K^{-1}$], liquids and gases also conduct via molecular vibrations
- The units show it is the energy transferred per m thickness of the material per K temperature difference over the thickness
- The thermal conduction is often slower than convection due to carrying hot fluid to areas of cold
- But in relatively motionless fluids, conduction is important, and especially at the boundary between solid and liquid where the velocity is zero, it entirely determines how much heat transfer can occur into the fluid from the wall

https://www.youtube.com/watch?v=UBcZsWJ5TNA&feature=youtu.be

What you can know from tables

- Tables p.1-4 are saturated steam
  - Boiling point temperatures vs. pressures
  - Specific volume of vapour
  - Enthalpy and entropy
- Tables p.5-9 are superheated steam
  - Enthalpy and entropy most useful
- Tables p.10 are water/steam
  - Specific volume, specific heat, viscosity, thermal conductivity, Prandtl number
- Tables p.15 is R134a refrigerant
  - Saturation temperature/pressure, enthalpy, entropy, specific volume
- Tables p.24 is the international standard atmosphere