On Heat and Quality

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Highly honoured Chancellor, highly honoured Rector, Ladies and Gentlemen.

Today is again a historic day. A not-Finn is the first to enter a professorship chair at Åbo Akademi University's brand new Faculty of Technology, which' largest department during the last century became known as the Faculty of Chemical Engineering. But, I was appointed to this position as of November 1, 2005 and I have my lectures for spring 2006 already behind me. Soon the exam for that will show how good those lectures were.

By introducing new people an organisation reduces the risc of collapse as a result of inbreeding. But I have been with Åbo Akademi earlier, from 1993 until 1997 and I have returned after 99 months with Helsinki University of Technology and the Academy of Finland. I came to Finland some time ago after studies at Delft University of Technology, specialised in particle technology and multi-phase flow and with some background in energy engineering. The Netherlands are not the best place for studying energy engineering. Almost all I know about heat and energy I learned in Finland. The result of studying technology at Delft followed by research and teaching in Finland now stands in front of you.

During 13 years in Finland I learned a lot about Finns and Finland-swedes, about languages, about being a foreigner, about driving a car during winter, about being ill and going to a physician in Finland. About how it went when the Finns became EU citizens like I'd always been. About that the police don't want to speak Swedish and that one visit to a sauna per year is enough for me. But regretably I did also learn how to control and manipulate by not doing anything, how to hurt and damage by being quiet and let be. "Management by not-doing". But I have also learned how the quality of life depends on clean air and clean water, with forest surroundings, with results instead of talking. And that an experimental plan is more important than a project steering board.

My chair has the name Engineering Thermodynamics and Modelling, with a teaching field that covers much more, as you can read in the invitation-booklet for this occasion. A groovy package, even for those who have some idea of the daily life of chemical engineers. I must say that the field is certainly large enough for me! In short, it deals with the physics behind chemical engineering, for which there is hardly any need for exotic, expensive or hazardous chemicals.

But – chemistry can not be neglected since a chemical reaction gives large changes in material streams through a process or factory. Chemical processes and reactions must of course obey the laws of physics. More problematic for chemists are those phenomena that do not occur in the laboratory but give question marks when a few tons of a certain chemical product must be put out. Most chemists in those cases go for the use of a catalyst while giving the physical limitations some thought might give a cheaper solution.

Being a thermodynamics professor is in itself rather special, since it deals with concepts and phenomena that we do not understand very well. Some time ago one professor at Helsinki University of Technology used to say: "There are only three people who understand thermo-dynamics and we meet once per year in Paris". I hope that the professor is still alive and that I will have a chance to discuss things with him sometimes. I would also like to know who the other two thermodynamicists are, or were.

But – back to the subject: thermodynamics is usually defined as a branch of physics that deals with descriptions of matter and especially how these depends on temperature, and with the conversion of energy. OK for my part and I hope that this satisfies also you, especially those among you who see themselves as "friends and active supporters of science". But not many of you would dare to write me a short e-mail message explaining what "temperature" or "energy" actually is, although it would certainly give me a lot of pleaseant reading and inspiration for the future.

One cannot be thermodynamicist without thinking every now and then: "what am I working with, what is energy, what is temperature, what is heat", etc. I want to try to explain to you how energy and heat should be experienced, and why thermodynamics is important. Nor only for those who study (chemical) process technology but also for those who feel that they have to take part in discussions on energy.

Working with energy is a bit complicated and laborious, especially when dealing with the type that is called "heat". On one hand energy is important in all we do, when we sit in a room with controlled temperature, light and humidity and work with a personal computer or another electrical device. Or when we travel around by bus, car, boat or aeroplane. Our own biological system is in constant need of food and soon it is again time to go and eat and drink something. We all do have some emperical understanding, which means based on experience, of what energy is. On the other hand we cannot see energy, while we know that energy is stored in a battery or a fuel, and that food and drinks contain calories, and that the sunlight can warm us and can even burn our skin.

Energy is nowadays an important political factor with a price for crude oil that steadily lies above 60 dollars per barrel, and pressure to increase the efficiency of energy use. We must reduce the combustion of fossil fuels as to limit the consequences of the global warming process that appears to be the result of human activities. We will need new energy sources that must be developed during the next decades. I will have to take part in that work. We may say that energy, food, clean air and water together with religious frictions and wars about pieces of land control the life of must of us. If we regard "energy" as a generalisation of the classic element "fire" then we are back with the for elements or cosmic building blocks water, soil, air and fire as defined by Empedocles 2500 years ago.

A complicating factor is that the behaviour of energy leads to wrong interpretations and the result is that we use energy like we use for example water. We take it from nature and turn it into a consumer product, i.e. drinking water, or electricity or a fuel. However, while the use of water results in polluted water, significant amounts of heat are produced in processes that require an energy input. Analogous to the use of water we are dealing with the degradation of the energy, and we should think a bit further about why heat is produced at all, especially when we wouldn't want that. We all know how hot something can become as a result of friction.

Heat should be interpreted as a by-product of energy use, and if the temperatuur of the generated heat lies near that of the surroundings then that heat is useless. We noticed that low temperature heat can be upgraded to heat of a higher temperature by adding energy in the form of, for example, electricity or fuel. The device for that is called a heat pump and many of you have one of those at home.

Energy has many quality-levels. The most important for process engineers are mechanical energy, thermal energy and chemical energy. (Besides these there is electrical – or better said electromagnetic – energy and several other types I don't want to bother us with today.) Mechanical energy has a long history, with use of human and animal force and the movement of wind and water in agriculture and for travel. Heat for heating was produced by burning wood and other biomass and wastes. During the middle ages the use of coal and peat started, followed by oil and natural gas during the last 150 years. For mechanical energy is became clear that it could be converted into most other energy forms in a reversible way, i.e. to and fro without any losses. For example, the kinetic energy of a moving object can be used to lift up another object, and vice versa. During the 18th century Bernoulli discovered a connection between static and dynamic pressure for tube flow. Shortly thereafter the need to pump large amounts of water from coal mines led to the development of the steam engine.

And at that point in history it became clear that heat was different and special, and that a certain amount of heat does not give the same amount of mechanical energy when converted, but less than that. The first thermodynamicists Carnot, Clausius and others developed the theorical fundamentals of heat during the 19th century. The most important results of that are the Laws of Thermodynamics. The First Law states that energy cannot be produced but can be converted into other forms. The Second Law states that heat can only partially converted into another form of energy while some part must be given off to the surroundings as losses. Which is not to hard to understand, since the use of hot steam for heating finally gives cold steam or water.

Thus, temperature is the factor that controls the quality of heat. And heat became defined as the energy form that is transferred by a temperature difference. The direct "link" between heat and temperature is entropy, as defined by Clausius around 1865. Heat is nothing else but hot entropy. At the absolute zero-point for temperature, 0 K, heat cannot exist and entropy is not defined.

Entropy is one of the largest mysteries of physics and a nightmare for many students and teachers. Entropy stands for chaos, or disorder, according to Boltzmann's reasoning around year 1900. The fact that the entropy of the universe can only increase with time doesn't make things less mysterious. It just adds more questions: what is time and what is disorder?

In the first theoretical study on heat, from the year 1824, Carnot still mixes the terms "heat" and "heat substance". Slowly but surely, however, it became clear that these are one and the same thing and that heat has no weight, or better said, no mass. This makes heat insensitive to forces, and gives the possibility to transfer heat as radiation. The heat of the sun comes to us that way. But a thing without mass does not respond to gravity. Together with Einstein's theory on gravity this means that "time" doesn't mean much for entropy. And why there is no such thing as "thermomechanics". It's a pity that Einstein hardly focused on thermodynamics; in his opinion it was a physical description that does not need much improvement, if any at all.

Entropy is a measure of freedom, and the entropy of a substance increases if its degrees of freedom increase. The entropy of the universe increases with time and so it has to be also here at our place. Chemists and process engineers often try to go against that rule, for example when producing polymers or in a crystallisation process. Tying together or building stacks of molecules decreases their freedom. The requirement that the entropy of the universe must increase always means that we will have to pay by giving of heat to the surroundings. The result is a heat effect that is inevitable. Gibbs has theoretically derived this more than 100 years ago, by combining the First and Second Law.

Although calculations are rather trivial, heat engineering is not that easy. It may be for that reason that many universities have a faculty of mechanical or “machine” engineering while I have never heard of a faculty of thermal or “heat” engineering or something like that. In that respect electrical engineering, based on an understanding that was developed around the same time, has managed to develop itself much beter. It may be for that reason why we now experience an energy supply problem.

The two Laws of Thermodynamics are of great importance to many fields. On the first place it means that energy cannot be produced but can be made accessible for use, in the form of electricity or fuel. Using energy means that it is transferred into for example flue gas, heat and other low(er) quality energy forms. But calculated as Joule, calory or kilowatt nothing changes. The electricity for a refrigerator is changed into heat at room tempeature and some sound, and both are useless. Although only the quality of energy is reduced this is experienced as energy consumption that must be compensated for with new energy that can be bought from a so-called “energy producer”.

It may be understandable why consumers that use energy mistakeably speak about “energy production”. But that specialists writing about energy in journals and magazines and even professors of technology speak about “energy production” is disturbing. It is certain that the amateurs who speak and write about “energy production” (or in Finnish: “energiatuotanto”) will not contribute to the development of new energy technology for the future. Electricty production, fuel production, heat production: all fine, but “energy production” is nonsense, always. Wrong use of terminology slows down progress.

The Second Law of Thermodynamics is of more use than the First Law in identifying energy degradation and losses. This is the first step towards making improvements that make energy use more efficient and effective.

To close this discussion on energy we can say that energy- and heat technology are directly responsible for the current greenhouse effect problem. Not all heat is coming from the sun. A large amount of heat is an end-product or by-product of the combustion of fossil fuels in chemical processes or for electricity production. Minimising the production of heat during the production of electricity would give a big improvement. In practice it would mean a strong increase in the use of fuel cells which allow for the direct conversion of chemical energy into electricity, with only a small heat effect. It would also mean an end to electricity production via a combustion step in furnaces, boilers, gas turbines and engines. It is time to replace the technologies developed during the period 1850-1950 with an improved energy supply structure that we will need in a future where fossil fuels will become scarce and too expensive. Heat should be produced only there where heat is needed, for example in a steel factory. Heat production should be based on heat and the use of heat pumps. Heat must not be produced as an intermediate towards another energy form since just this wil give losses.

Thermodynamics is also a good starting point for research and teaching in, for example, refrigeration, mass transfer, fluid mechanics or separation processes. Things like turbulence, irreversible thermodynamics and phase equilibrium give extra flavour but in the end it all comes down to the same thing. Unfortunately, I must keep some material for my lectures.

To end this lecture, a few words on engineering training at Finnish universities. Year 2006 is also Year One After Bologna, where also Åbo Akademi in 2005 joined the new structure for university education. The idea is that students get more possibilities to take part of their study program at different locations.

An advantage is that Finnish and also foreign students who experience the Swedish language as a problem now can take courses everywhere under master-programmes with teaching in English. Åbo Akademi can compete better with other Finnish universities in such a situation. A disadvantage for Finland, however, is that the countries that join the Bolgna system should all offer teaching of more or less the same quality level. This means that my second-year course on heat engineering should be equivalent to a second-year course in heat engineering at for example a German or Spanish university. I should not give lectures using material that is used for gymnasium teaching abroad. One large advantage of the Bologna system is that the quality of universities will go up inside the EU and certainly also outside.

Several recent studies have shown that Åbo Akademi is the best or one of the best in Finland when it comes to effectiveness and quality. However, being the best in Finland is not enough if it also can mean being amongst the worst of the Nordic countries and unknown outside that region. One should not compare oneselve with oneselve, or only with the neighbours on the left and right side. Certainly Åbo Akademi is the best swedish-speaking university in Finland. The Bologna system demands that Åbo Akademi is compared with universities of about the same size, for example at York, Karlstad, Twente, Orléans, Venice or Crete.

The Bologna system means more than that 36 studies per year in Finland (or 42 study weeks in the Netherlands) will now be counted as 60 study points. I do not think that I am the only one who has noticed that our courses are too easy for students from what earlier were the other EU-15 countries. At the same time students from those countries that recently joined in what is now the EU-25 often have big problems. Our Finnish university training for process engineers must be improved if it is to be relevant from an EU or other international perspective, because its level lies clearly below the EU-average, even after May 1, 2004.

Much better is the situation for our Doctors of Technology who apparently succeed in catching up with their colleagues abroad. This is nice, because a Finnish doctors-hat is not meant as a protective helmet for withstanding international competition. But the price for it is that a PhD study typically takes much more than 4 years. Partly the supervision and guidance by the professor is a failure if a PhD study is not finished after 5 years. But an improved engineering training to the MSc level would not only benefit our future PhD students but all graduating engineers. It must be possible to do the studies for Masters degree abroad after studies for Candidate level in Finland. Then it will be possible later to do the PhD studies abroad as well, where study time is often limited. One should not for safety's sake take the Finnish Licentiate degree before embarking on a PhD study abroad, although I would actually recommend that at this moment.

If in the entire EU the masters-programs, i.e. the 4th and 5th year, are taught in English then it will be easier to compare teaching material of different universities and even take that into use straightway.

Little things like that will speed up the Bologna process. What remains is the problem that the exams for Candidate and Masters degree under the Bologna structure are not directly comparable with the Bachelor and Masters degrees in the USA……

I will do my best to be a worthy successor to Carnot, Clausius, Boltzmann, Gibbs and of course Åbo Akademi- professors Von Schalien and Öhman. I know from experience that defining a problem is the first step to solving it, and I have noticed that many problems are soluble in eachother and might thereby disappear.

I bring with me from Holland the tradition and way of thinking of Kamerlingh Onnes and Van der Waals, physics professors at the University of Leiden. I was born only a few kilometers from Kamerlingh' Onnes laboratory. They did research with very low temperatures and with super-critical systems at high pressure and temperature, at the end of the 19^{th} century. I myself will address entropy although I do not know yet how that will look in the laboratory. For example: how is entropy related to heat radiation, and how can entropy production in separation processes be minimised. The extension "and modelling" to my chair implies that I will probably use a computer every now and then but not without necessity. The Marquis de Sade has once said: "One should not replace the truth with something that is impossible".

I thank Åbo Akademi for giving me the wings with which I can fly over my field. On the other hand I am well aware that also Åbo Akademi is ambitious by at the end of 2004 asking me to apply for this job, presumably aiming at flying higher too. Questions that remain today are: is there anything to be done up there, and how much time will I actually get.

I thank you for your attention.