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High profitability through ecological based insulation thicknesses

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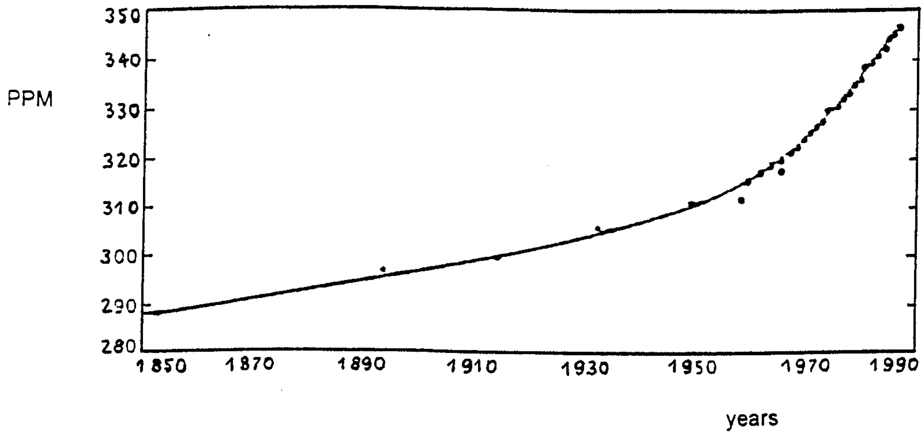
Contents

1. Foreword

The expenditure of fossil energy not only exhausts the available resources of primary energy, it moreover constitutes a strain on the environment through the associated emission of carbon dioxide.

CO_2 in the atmosphere absorbs the thermal radiation emitted from the surface of the earth, thereby reducing the heat transfer into space. With an increasing percentage of CO_2 in the atmosphere, a global temperature increase occurs, known also as “green house effect”, the consequences of which are not as yet totally estimable.



(Concentration of carbon dioxide in PPM (parts per million, one thousands %o))

Figure 1: Development of CO_2 concentration in the atmosphere /1/

Primary energy sources show differences in their CO_2 emissions. Natural gas is lower than crude oil or coal due to its higher proportion of hydrogen and its lower proportion of carbon.

CO_2 originates from the burning of carbon, that is to say in generating thermal energy. No technique is available for the retention of CO_2 as is the case e. g. with SO_2 or No_x, which can be filtered out of the exhaust in flue-gas cleaning installations. The only way the CO_2 concentration in the atmosphere can be influenced is to prevent the origination of CO_2 in the first place.

A reduction of the CO_2 emissions is only possible through savings in the consumption of fossil energy sources. Heat retention is a significant contribution to this.

This letter aims at the clarification of the following:

- An increase of insulation thickness in excess of the economic optimum is indispensable to achieve a reduction of CO2 emissions.
- An increase of insulation thickness is operationally not “expensive”.
- The investment needed for heat retention have extremely short pay back periods.

2. Internationally recognised necessity to minimise CO_2 emissions

At the Rio de Janeiro conference on the environment, the international community has committed itself to reduce the CO_2 emissions. Individual national reduction targets ranging from 20% to 30% up to the year 2005.

This extraordinary ambitious aim can only be achieved by an enormous effort in all areas concerned:

Heat recovery, achieving higher degrees of efficiency, employment of renewable sources of energy in the form of wind or solar energy or biomass and the substitution of energy sources rich in carbon, such as coal, through energy sources with a lesser content of carbon, such as natural gas, are some catch phrases. **However, energy savings are of special importance.**

As an example for the magnitude of emissions in an industrialised country, Figure 1 shows the CO_2 emissions in the Federal Republic of Germany in 1987. Additionally, 300 million tons of CO_2 are emitted by human respiration.

	million tons of CO_2	%
Domestic heating	149	21,4
Households and small consumers	37	5,4
Power plants and district heating schemes	252	36,3
Road traffic	137	19,7
Industry	120	17,2
Total	695	100,0

Figure 2: CO_2 emissions 1987 in the Federal Republic of Germany /2/

3. Possibilities for heat retention in industrial installations

The energy consumption in industry in the example given in Figure 2 is of roughly the same magnitude as that in domestic heating. Considering the conversion of energy needed in power plants and district heating schemes, it is even higher. Effective heat retention and energy savings in industry, therefore, constitute a significant contribution to the generally accepted goal to reduce the CO_2 emissions.

Heat retention contributes to the protection of resources through energy savings and – since the exhaust is also reduced – to the protection of the environment. Therefore, the future sizing of insulation thicknesses is of exceptional significance.

VDI 2055 /3/ points out:

> *“Bases for calculating the insulation thickness are operational and economical. However, aspects of environment protection play an increasing role.”*

4. Increasing the insulation thickness

This investigation seeks to find out which influence an increased heat retention has on insulation thicknesses, cost and profitability of insulations of industrial installations. /4/

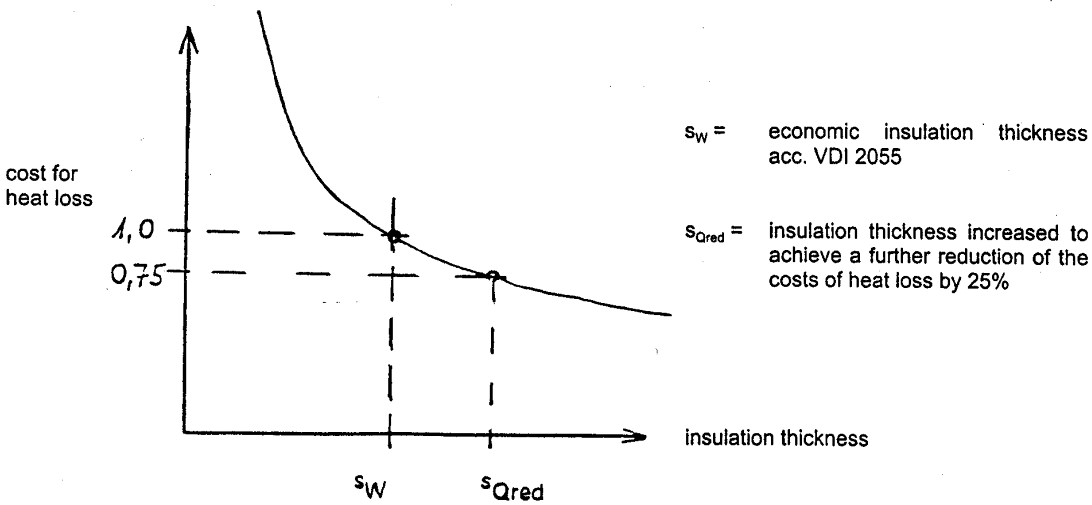


Figure 3: Relationship between the cost of heat loss and the insulation thickness

As an example, three pipes with nominal diameters NB 40, NB 150 and NB 500 are considered, using different fluid temperatures. In excess of the reduction of the heat loss expenditure, which is achieved by the “economical” insulation thickness according to VDI 2055 /3/, an additional reduction of heat loss expenditure by 25% is assumed. The insulation thickness needed to achieve this is called “ecological” insulation thickness (S_{Qred}).

Starting with the current economical insulation thicknesses, the percentage increases emerge for the insulation thickness as shown in Figure 4.

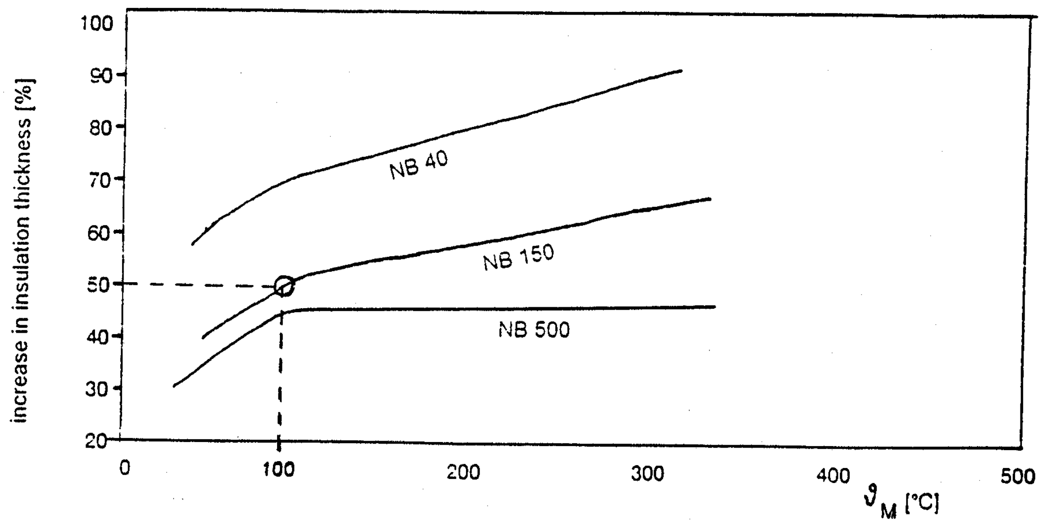


Figure 4: Percentage increase in insulation thickness to reduce the heat loss by additional 25%

Example: To reduce the heat loss by the assumed 25% at an operating temperature of ϑ_M = 100 °C and a nominal diameter of NB 150, a 50% increase of the insulation thickness is needed.

Dependent upon nominal diameter and fluid temperature, the required increase of insulation thickness lies between 40% and 100%, at small diameters the influence of curvature and the enlargement of the surface with increasing insulation thicknesses exert a strong influence.

The increase of insulation thickness needed for a further reduction of heat loss by 25% is considerable, and to question the associated cost increases is entirely justified.

These costs will be more closely considered in the following chapters, however, only calculating the actual insulation costs excluding costs of installations and buildings.

5. Economic insulation thickness

The economic insulation thickness S_W according to VDI 2055 /3/ is shown in Figure 5.

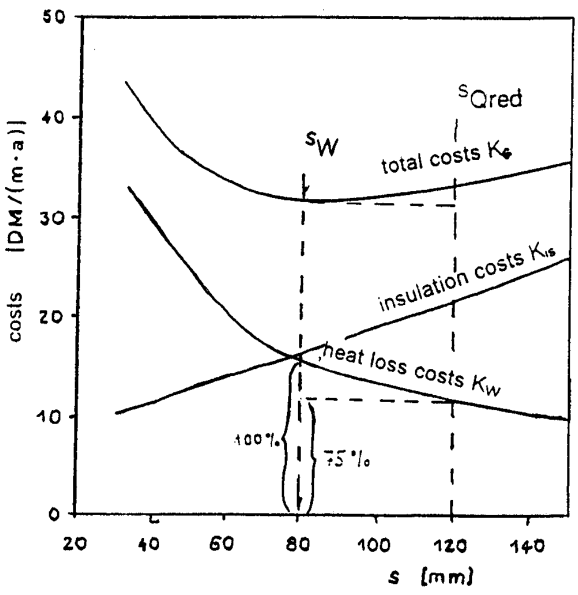


Figure 5: Economic insulation thickness and costs for an additional reduction of heat loss by further 25%

The economic insulation thickness is that thickness at which the total insulation costs per year plus heat loss costs per year are at a minimum. Increasing prices for thermal energy move this minimum to the right in direction of higher insulation thickness. The costs for heat loss K_W are obtained, using the price of thermal energy, the energy lost and the annual number of operating hours.

In this calculation, one must not use the actual prices for thermal energy, but additionally consider their future price. Omitting increasing prices will result in insulation thicknesses being too low, which are then no longer economical.

So, VDI 2055 /3/ must be welcomed, offering a calculation method, with the aid of which the estimated price increases can be accounted for through a dynamic factor.

6. Environment protection and economy

Two fundamental observations are necessary:

1st observation
If the insulation thickness is based on ecological considerations, the result is an insulation thickness which is not operationally optimal. This insulation thickness is called “ecological” insulation thickness to mark the distinction from the economical thickness.

2nd observation
To appreciate the cost increase for the 40% to 100% higher insulation thickness needed according to Figure 4, one must not only consider the pure investment cost for the insulation. Additionally, the resulting savings in costs for energy lost must also be calculated. Only the total costs are of importance.

The cost curve shown in Figure 5 for a pipe of a diameter NB 150 and a fluid temperature of 100 ℃ is very flat in the vicinity of the economic optimum. This means that the total costs increase only marginally, despite a significant increase in the insulation costs, as the savings in costs for energy lost are still very high.

7. Additional costs for “environment oriented” insulation thickness

Figure 6 shows how the total costs change as the heat loss is reduced. In the left part of the table, the economic insulation thicknesses based on VDI 2055 /3/ and the increased insulation thickness (S_{Qred}) are listed.

NB	ϑ_M [℃]	S_W [mm]	S_{Qred} [mm]	ΔK_W	ΔK_{is}	ΔK_G
				%		
40	50 100 300	40 50 110	65 86 210	-25	45 56 110	17 9 22
150	50 100 300	50 80 160	70 120 260	-25	18 32 71	5 4,5 18
500	50 100 300	70 110 200	95 160 300	-15	17 25 40	3 4 8

Figure 6: Cost increase to reduce heat loss by 25%

Example: NB 150; fluid temperature 100 ℃
Increasing the insulation thickness from 80 mm to 120 mm means an increase by 50% (Figures 4 and 5), however, it reduces the costs for heat loss by 25%. Thus, despite an increase of the insulation cost by 32%, the total costs are only increased by 4,5%.

In the right-hand side of the table, the percentage change of the respective costs is listed: costs for heat loss K_W decrease by 25%. The costs for the insulation K_{is} increase by 15% to 110%.

The total costs – shown in the last column – however increase in a considerably lesser measure. Their rates of increase lie between 3% and 22%.

The results show that energy saving and thereby a reduction of the CO_2 emissions through improved thermal protection is a comparatively economical and profitable exercise.

8. Pay Back Period (PBP)

Despite these results, the question is raised as to whether the increased investment costs can be justified in the first place. Considerations on profitability are frequently guided by the allegation that the insulation was more expensive than the piping itself. Even where this observation is true, it does not say a thing about the profitability of the insulation.

A gauge of the profitability is the Pay Back Period, in this case the time span needed to recover the costs for the investment through savings in the costs for heat loss. The PBP is calculated as follows:

$$PBP = \frac{\text{investment cost}}{\text{annual savings}}$$

Figure 7 shows the calculation of the Pay Back Period using the example of a pipe of NB 150 and a fluid temperature of 100 °C with an (economical) insulation thickness of 80 mm. For this, the Pay Back Period is 0,5 years. The cost unit is DM; this does not affect the resulting PBP.

Piping NB 150	ϑ_M	:	100 °C; s_W = 80 mm
Heat loss without insulation	$\dot{Q}$	:	0,460 kW/m
Heat loss with insulation	$\dot{Q}_{is}$	:	<u>0,040 kW/m</u>
Savings		:	0,420 kW/m
Savings per year (ß = 8700 h/a)	$\Delta\dot{Q}_ß$	:	$3654\ kWh/(m \cdot a)$
Costs for thermal energy W (12,50 DM/GJ)		=	0,045 DM/kWh
Annual saving		:	$165\ DM/(m \cdot a)$
Pay Back Period	PBP	≈	0,5 a

Figure 7: Calculation of the Pay back Period PBP

PBP ≈ 0,5 a means that in this example the investment capital has already been recovered after six months through savings in energy costs. Such a short Pay Back Period, also called amortisation time, shows that insulation is extremely profitable. Its profitability is unlikely to be rivalled by that of any other industrial investment.

Figure 8 shows the Pay Back Period for pipe insulations using current insulation thicknesses (PBP) and for obtaining additional 25% energy savings through increased insulation thicknesses (PBP*).

NB	ϑ_M [°C]	PBP [a]	PBP* [a]
40	50	2,5	3,6
	100	0,7	1,1
	300	0,2	0,4
150	50	1,6	1,9
	100	0,5	0,7
	300	0,09	0,15
500	50	0,34	0,36
	100	0,11	0,14
	300	0,025	0,027

Figure 8: Pay Back Period PBP for economical insulation thicknesses according to VDI 2055 /3/ and PBP* for an additional reduction of heat loss by 25%

Example: Piping NB 150; fluid temperature ϑ_M = 100 °C;
PBP for economic insulation according to VDI 2055 /3/: 0,5 a (6 months).
PBP* for insulation for a 25% increased energy saving: 0,7 a (8,4 months).

Figure 8 shows in the third column the Pay Back Period of an insulation calculated according to VDI 2055 /3/. It is the shorter, the higher the fluid temperature.

In the fourth column of Figure 8, the Pay Back Period times for insulations are shown which have been increased to exceed the economic optimum aiming at an additional 25% energy savings. It is only marginally higher.

9. Summary

Considerations of Pay Back Periods show that reducing the heat loss through insulation is an economic and effective method to save energy. If the insulation thickness is increased in excess of the economic optimum to meet an "ecological" standard, the Pay Back Period PBP* is even then only marginally increased: environment protection through insulation is very inexpensive!

A small additional investment can constitute a significant contribution to reduce CO_2 emissions!

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Note: A European standard, reflecting principally the same philosophy as VDI 2055, is in preparation in CEN/TC 89: “Calculation of the optimum economical thickness of insulating layers”.

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