Purdue University
Purdue e-Pubs

International Refrigeration and Air Conditioning Conference

School of Mechanical Engineering

1994

Total Environmental Impact of a Small Hermetic Compressor

P. E. Hansen
Danfoss Compressors GmbH

V. Gustafsson
Danfoss Compressors GmbH

I. Drabaek
de-Teknik

A. Schmidt
de-Teknik

P. B. Pedersen
de-Teknik

Total Environmental Impact of a Small Hermetic Compressor

By
Poul Erik Hansen, Vibeke Gustafsson
Danfoss Compressors GmbH. P.O. Box 1443. D-24939 Flensburg. Germany.
Tlf int. + 49464941-109, Fax int. + 494614941-629

Iver Drabæk, Anders Schmidt, Preben Buhl Pedersen
dk-Teknik, Gladsaxe Moellevej 15,
DK 2860 Søborg, Denmark

ABSTRACT

The relative energy consumption caused by the introduction of the alternative refrigerants has been seen as very important while replacing the CFC's. In the framework of the TEWI concept the influence of alternative refrigerants on the global warming is calculated, taking into account the direct and indirect effect. This paper extends these analyses as it includes the influence of a hermetic compressor in its total lifetime from the production of raw materials to the disposal of the compressor. Further an analysis of the emission of SO_2 and NO_X is given and the amount of waste is estimated.

Finally the analysis is used on an energy optimised compressor for the European market. In order to increase the energy efficiency the compressor producers are normally forced to use more materials, e.g. copper wire. It is demonstrated that the energy consumption due to the use of more materials is tenfold regained by the reduction in energy consumption in the lifetime of the compressor.

INTRODUCTION

Life cycle analysis (LCA) can be defined as an inventory of the environmental impacts of a product from the production of raw materials to the final disposal of the used product.
LCA is being used for an increasing number of purposes. Most applications have so far been comparisons between different products serving the same purpose. Lately LCA has been used while product development to include the knowledge of potential environmental impacts of products.
The analysis in this paper will provide a comprehensive view of the environmental impacts from a typical compressor (TL5F) in its life cycle.Furthermore a comparison of the environmental impacts of a standard compressor (TL5F) with the corresponding energy optimised compressor (TLES5F) is presented.
The compressors used in this analysis are hermetic reciprocating compressors with stroke volumes of 5 cm^3 used for domestic refrigeration with the refrigerant R134a. At the standard rating point of 25°C/55°C/32°C the TL5F has a COP of 0,82, the TLES5F a COP of 0,96.

METHODOLOGY.

The present paper excludes the evaluation of the environmental impacts. Some choices have had to be made, e.g. the analysed geographical area. These choices, as well as other limitations in the study will be clarified in the following paragraphs. Key parameters of the analysis will be presented, but some results that may be of relevance in a complete analysis or assessment of the life cycle have been omitted.
The analyses include the following phases of the life cycle (figure 1):

* Production of raw materials
* Production of components
* Production of the compressor
* Assembly and sale

* Use of the compressor
* Scrapping
* Recovery of raw materials (copper)

The functional unit

Defining a functional unit is very important in a LCA because it is the basis for both analysis and comparisons. In the present study the functional unit is: **Use of a compressor in a household refrigeration unit in an assumed unit lifetime of the unit of 12 years.**

Life cycle phases and data quality

The inventory focuses on the conditions found in Germany and gives a general view of the environmental impacts of a compressor that is produced, used and disposed of in Germany under conditions found in 1992/93.

The data quality is not equal for all phases in the LCA. For the phase "Production of raw material" old data have been used in most cases. The age of the data is of minor importance as new technologies have not emerged during the recent years. The impact from production of some of the materials (e. g. the plastics) have been estimated conservatively. As these materials only form a minor part of the compressor, the error introduced with this is very small.
The phase "external production of components" was analysed by making analogies to the production at Danfoss Compressors. This is because only few data from suppliers to Danfoss Compressors were available.
"Production at Danfoss Compressors" was analysed using a black box approach. In all calculations the annual impact from the production is equally distributed on all compressors, despite special conditions. The environmental impact from operation and maintenance of the production facilities was included in this phase. Whether this is the case for the other phases are not clear.
"Assembly and sale" was analysed using data from only one producer of refrigerators. It was assumed that the best available technology is used. The compressor is used in a small refrigerator with a net volume of 144 litres.
"Use of the compressor" was analysed using the following energy mixture:

58.2% Coal
27.8% Nuclear power
7.5% Natural gas
3.1% Hydro electricity
2.0% Oil
1.5% Other

The average efficiency in electricity production was assumed to be 37.4%, equal to the German average for conventional power production. When a general knowledge was present emissions, i.e. SO_2, NO_x and CO_2, were included in the analysis. It was assumed that no changes in the energy mixture will occur during the use phase. The energy consumption was calculated according to a model developed at The Institute of Physics, Technical University Of Denmark.
The calculations were corrected for the heat production from the compressor and the waste from the energy production was calculated and included.

In the "Scrapping" phase it was assumed that the compressors from Danfoss Compressors are treated like average compressors, i.e. 40% are recycled in "informal circuits" and 60% are sold to a copper mill for recovery of the copper. Scrapping and disposal of the refrigerator (inclusive the compressor) was assumed to take place at a modern German scrapping plant. A compressor produced in 1993 will use R134a, but a compressor that is being scrapped in 1993 was produced 12 years ago and has used R12 as refrigerant. Since it is very difficult to estimate the development of scrapping technology, it was assumed that best current technology will be used.
In the analysis of the "Copper Mill" it was assumed that the copper is recovered while all other residues are disposed of as waste, e. g. fillings for roads and ditches.

The impact from transportation is less than 0,1 percent of the impact in the use phase and is only estimated. An

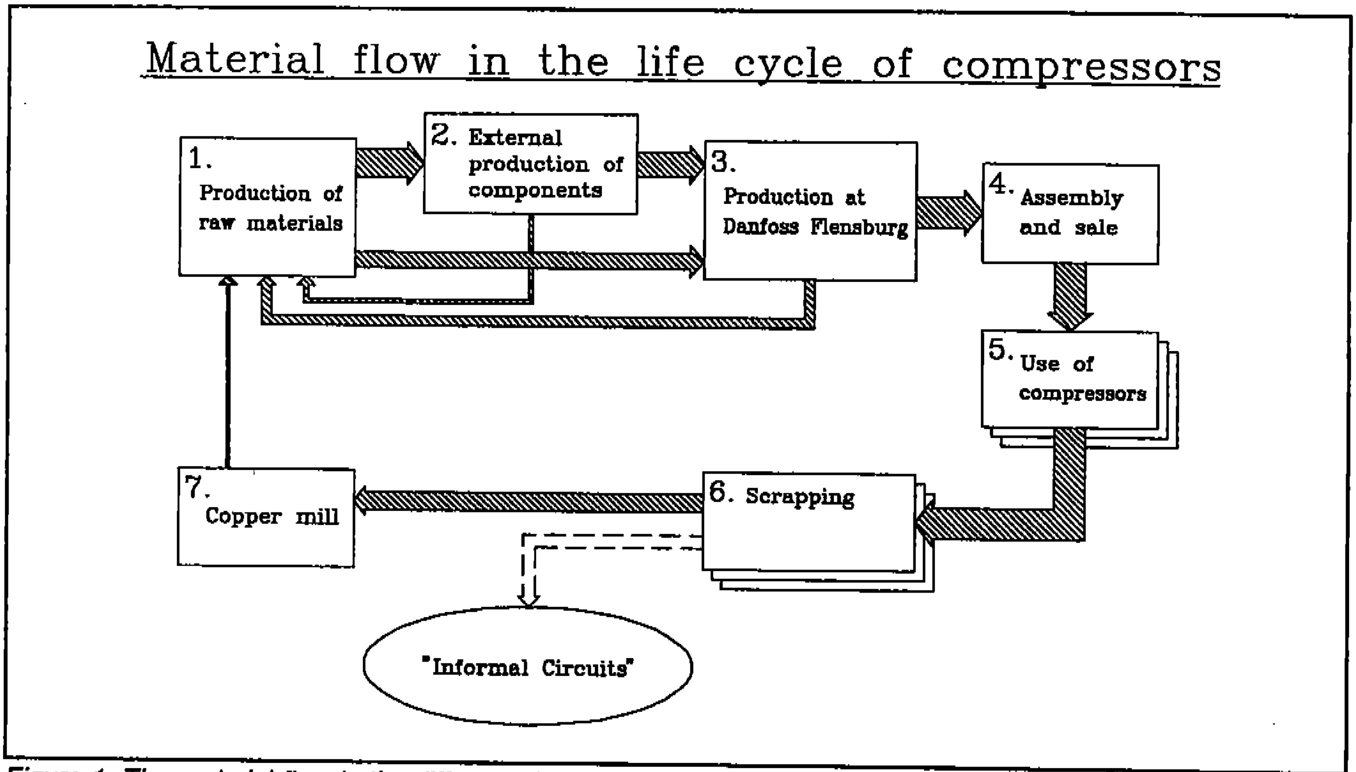

Figure 1. The material flow in the different phases of a life cycle of a compressor.

even smaller contribution comes from the packaging materials, mainly wood.

RESULTS

Key parameters	Consumption of raw materials (kg)	Consumption of primary energy (MJ)	Emission of CO_2 (kg)	Emission of SO_2 (g)	Emission of NO_x (g)	Heay ymetals	PAH	Dioxins	Refrigerant (g)*	Waste (kg)
Production of raw materials	61	281	24,9	80,5	44	x	x	x		48,9
External production		59,7	6,6	15,5	13	?	?	?		0,96
Production at Danfoss Compressors		93,9	10,4	24,3	20,5	x				1,33
Assembly and sale		0,1							0,01	
Use		29800	1100	1600	3000	x	x			15,7
Scrapping	-0,4	1							1,6	7,6

* In the phase 'Assembly and sale' the refrigerant is R134a used in the TL5F; In 'Scrapping' the refrigerant is R12 which is used in older compressors.

Table 1. Key parameters in the life cycle of a compressor (TL5F).

In table 1 and figure 2 the impacts in the life cycle of a compressor is presented. It is obvious that the use phase is the most important with respect to both consumption of primary energy and emissions. However, it should also be noted that heavy metals and polycyclic aromatic hydrocarbons (PAH) are present in several phases of the life cycle. The emissions of these compounds have not been quantified.

The materials produced in the phase "Production of raw materials" enter the life cycle in three subsequent phases. The final compressor weighs 7,8 kg.

COMPARISON BETWEEN THE TWO COMPRESSORS

The difference between the two compressors is found in the phases "Production of raw materials" and "Use". The difference in "Production of raw materials" is shown for some key parameters in figure 3.

The difference in the consumption of raw materials is mainly caused by a use of more copper (approx. 137 grams) in the TLES5F. The copper content in an ore is less than 1%, so the use of additional 137 grams of copper will accordingly increase the consumption of raw materials with 14 kilos. The use of iron in the TLES5F is less than in the TL5F, but totally the TLES5F consumes more raw material than the TL5F, although the final compressor weighs less. The bigger consumption of energy in the production of raw materials for the TLES5F is also caused by the increased amount of copper.

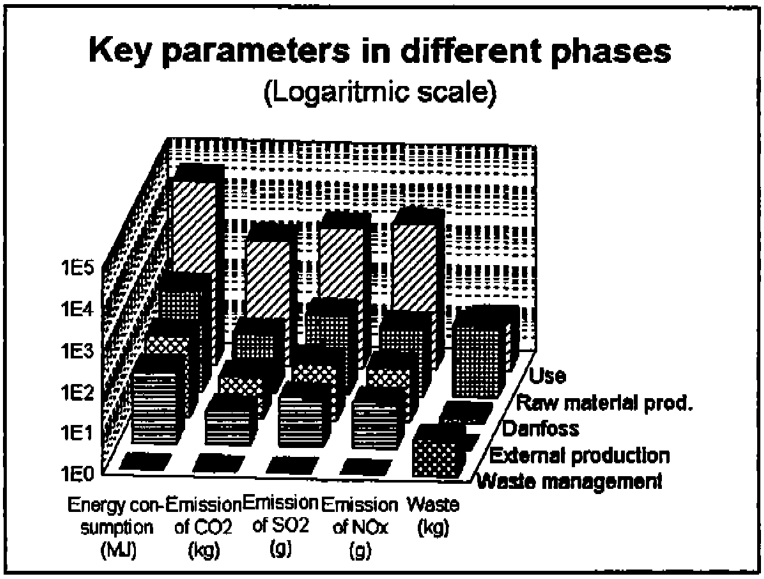

Figure 2. Key parameters in different phases of the life cycle of a compressor (TL5F).

The difference between the two compressors in the use phase is demonstrated in figure 4. As can be seen, the TLES5F consumes about 9% less primary

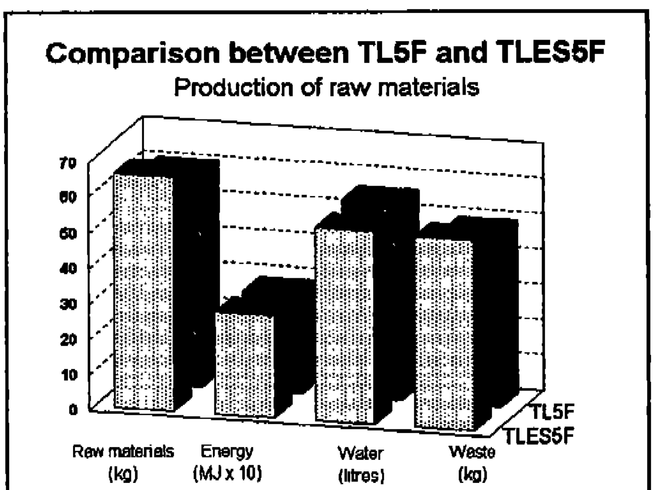

Figure 3. Comparison of key parameters in production of raw materials for two compressors.

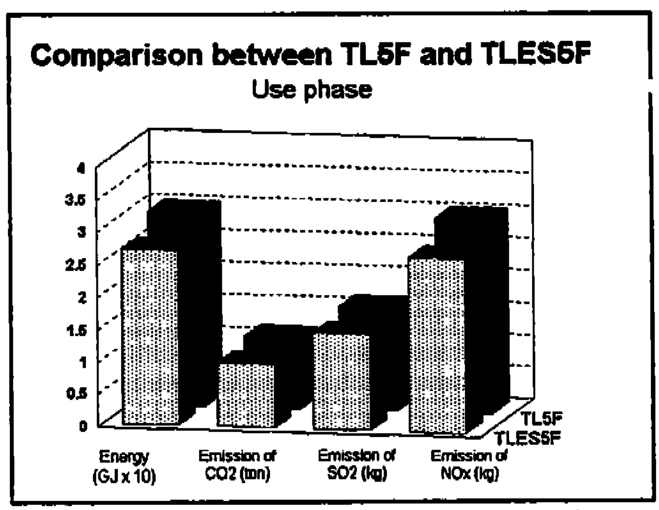

Figure 4. Comparison of key parameters in the use phase of two compressors.

absolute consumption of energy, this decrease becomes more significant as the energy consumption in the use phase is 99% of the total consumption in the whole life cycle. **The decrease is thus 10 times the total consumption in all other phases.**

In all other phases only minor differences between the two compressors can be found. It should be noted that the extra copper used in the TLES5F will be partly (60%) recovered in the scrapping phase.

CONCLUSIONS

The analysis shows that the major part of the energy consumption of a compressor takes place during the "use" phase. For a typical compressor the consumption in the use phase is about 99% of the total energy consumption. Improvement in terms of a reduced environmental impact should therefore concentrate on this phase.
This is similar to the conclusions from the TEWI analysis of refrigerants (3). The direct contribution on global warming from a refrigerant is only a minor fraction of the indirect contribution, i.e. the energy consumption in the refrigerator.
A comparison between a standard compressor and an optimised compressor shows that a reduction of 9% in the energy consumption has been accomplished, equal to 10 times the total consumption in all other phases. The "investment" of more materials e.g. copper, pays well off on the total energy balance.

REFERENCES

1. National Energy Data Profile - Federal Republic of Germany. World Energy Counsel, 15th W.E.C.Congress **1992**. German Member Committee.

2. *Anders Schmidt et al.*, "The Danish Materials Technology Programme. The frame programme for integrated environmental and occupational assessment." Methodology appendix., Feb. **1992**.

3. *AFEAS, US. Department of Energy*, "Energy and Global warming Impacts of CFC Alternative Technologies", DEC **1991**.