The Norwegian heat pump prototype and demonstration program

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1. SYNOPSIS

The Norwegian Heat Pump Prototype and Demonstration Programme has been run for 10 years. Through this, the operation of about 50 HP installations has been documented.

2. ABSTRACT

In Norway we have found that prototype and demonstration plants is one of the most efficient ways to spread knowledge of heat pump (HP) technology.

The Heat Pump Protype and Demonstration Programme was established in 1983, and about 50 installations has been given financial and technical support. The last few years, we have given priority to supporting heat pump plants with alternative working fluids to the CFCs. From an environmental point of view, "natural" working fluids like NH3, H2O, CO2 and propane seems to be most appropriate, and these will be preferred.

This poster to the ECEEE 1993 Summer Study presents the Norwegian authorities' aims and efforts towards introduction of heat pumps that use natural working fluids in addition to the results from operation of the prototype and demonstration (P&D) installations.

3. INTRODUCTION

From 1989 to 1992 the Norwegian National Heat Pump Programme has been run with funding from the Royal Norwegian Council for Scientific and Industrial Research (NTNF), the Norwegian Water Resources and Energy Administration (NVE) and the Federation of Norwegian Energy Utilities (NorEnergi). The main aim of this programme was to transfer HP technology from research and development (R&D) to the market. Besides, the aims were:

- to increase the use of heat pumps (HPs) as an energy and economically efficient and environmenally "friendly" part of the Norwegian energy supply system,
- to create a market for Norwegian suppliers of HPs and stimulate and contribute to quality in all parts of the HP deliverances and with consideration to the maintenance and operation of HPs,
- to engage in international cooperation and exchange of experience from the use of HPs in an effort to the international increased use of HPs, and
- to demonstrate HPs with alternative working fluids to the CFCs.

One part of the national HP Programme has been the Heat Pump Prototype and Demonstration Programme (HP-P&D) which has given both financial and technical support to the installation of different HP plants. The aim of this has been to contribute to the increased used of HPs in Norway by testing and demonstrating HP technology in practice in order to increase knowledge and experience in planning, building and operation in different applications. NVE is in charge of the financial support, while SINTEF Refrigeration Engineering takes care of the technical assistance.

By the end of the national HP Programme, about 50 HP demonstration installations have been given financial and technical support. Results from operation of these plants have been thoroughly documented and will now be spread in different ways. Among other efforts, the poster presented to the ECEEE 1993 Summer Study shows the main results from the HP-P&D.

In recent years, one particular barrier to the introduction of the HP technology has been given increased attention. This is the problem of the CFCs and their contribution to the green house effect and their negative effect on the ozon layer. To overcome this barrier, the Norwegian authorities will start a new HP Programme that will run from 1993 to 1997. Norway will put a particular focus on the use of "natural" working fluids like NH3, H2O, CO2 and propane in HP installations.

The new HP-Programme will be carried out through different activities, like information and education of different target groups, development of planning material and RD&D on heat pump installations using natural working fluids.

4. METHODOLOGY

The procedures of incorporating heat pump P&D plants are as follows:

- the owner of the building/plant applies for grants from the NVE in order to realize a heat pump project
- NVE evaluates the project in cooperation with SINTEF Refrigeration Engineering
- Plants that are given financial support (from the NVE) is followed up by the SINTEF through measurements during at least one year of operation

The results from each HP-P&D installation project are presented in brochures and technical reports.

It is important to notice that in Norway electricity is prodused by hydro power, which gives no emissions like CO2 etc. This means that in Norway operation of heat pumps have no negative effects on the environment.

5. RESULTS

5.1. Experiences from P&D plants in the periode 1980-90

In 1992 the results from the operation of 40 different heat pump installations which were built in the periode 1980-89 were concluded (Eggen 1992). Table 1 (Table 1 appears at the end of the paper) gives some main figures from these HP P&D plants.

Most of the heat pumps have been working well and contributed to profitable energy savings. However, the investigation has also discovered a number of problems concerning the design and operation of the plants.

5.1.1. Design problems

The design problems were most typical in the first HP P&D installations. The most common problems were:

- installation of too large HP due to overestimated heat demand in the building. A large and expensive heat pump means short operation time and bad profitability. For conventional heating (e.g. electric heaters etc.) an overestimation of the heat demand will not effect the specific heat cost very much, since the extra investment is rather low. For a heat pump, the situation is rather different, because it is cost intensive. Besides, a too large heat pump results in long periods at part load conditions, which is bad for the COP.

- the heat pump operating against unnecessary high heat distribution temperatures. This means reduced COP and reduced profitability

- improper control of the heat pump, leading to input of peak heating before the heat pump is operated at maximum capacity

5.1.2. Compressor failures

After operation time between two and eleven years, there have been compressor failures in 16 of the 40 HP plants. Most of the compressor problems were found in heat pumps working against high temperatures on the heat distribution systems. This means reduced lubricaton properties of the lubricating oil, which may lead to compressor failure.

5.1.3. Sea water as a heat source

14 of the plants use sea water as a heat source. Long time operation, 2,5 to 10 years, shows that only two installations had growth of seaweed and scallops in the sea water system. Cleaning of the systems easily solved this problem.

In three other plants, sll installed in 1982, the evaporators corroded. The evaporators were replaced with components of a different material which eliminated the problem.

The main problem in sea water systems seems to be the sea water pump. In 10 of the plants, the sea water pump has had to be replaced within only 2 years of operation. Even though this causes extra expences for the heat pump operation, it has not meant a serious hindrance to the heat pumps.

5.1.4. Air based heat pumps

14 of the heat pumps were air based. 7 of these were designed for a cold climate, and these have performed well. The other 7 have been standard units developed for the air conditioning market. The characteristic feature of these are finned tube air coolers with narrow fin spacing (1-2 mm) which require frequent defrosting. Most of the standard units were installed in greenhouses in the south-western part of Norway in the periode from 1983 to 1986. These units performed well for 7-8 years, but after that, the outdoor unit (evaporator) of two of the heat pumps have collapsed due to corrosion.

5.1.5. Waste and ground water based heat pumps

These heat sources are characterized with relatively constant temperatures all through the year which are favourable to the operation of heat pumps. No problems have occured in connection with the low temperature heat source system neither for the six ground coupled heat pumps, nor for the six waste water heat pumps that have been investigated.

5.2. Heat pump plants with alternative working fluids

From 1990 onwards, it has been given priority to supporting heat pumps with alternative working fluids to the CFCs like NH3, HFK-134a, HFK-152a and water. Table 2 shows the main data for these P&D plants.

5.2.1. District heating plant at Bodø Airport

The traditional way of building heat pumps for district heating is having one central plant for heating the water up to the necessary temperature level. This is an efficient and economical heating system in areas with a large, concentrated heat demand, and especially, with an already existing distribution grid, like at the

Table 2. *Main data for P&D plants with alternative working fluids to CFCs*

	Plant	HP-capacity (kW)	Working fluid	Start of operation
SEA WATER BASED HEAT PUMPS				
1	HP-District Heating, Bodø	2000	NH_3	1992
2	Sjøkrigsskolen, Bergen	400	HFC134a	1993
3	Vallersund Gård	40	HFC152a	1992
4	University in Bergen	2500	NH_3 *	projecting
5	Åsgaard Sykehus, Tromsø	1500	HFC134a	feasibility study
6	Veritas, Høvik	2000	NH_3**	feasibility study
AIR BASED HEAT PUMPS				
7	Bjørnheim B/L, Oslo	65	HFC152A	1990
8	SINTEF Adm.building	95	HC290	feasibility study
9	Bjørnheim B/L, Oslo	65	HFC134a	1993
GROUND COUPLED HEAT PUMPS				
10	Bølerskogen Borettslag	40	HFC134a	1993
11	Skårsetlia Kirke,Lillehammer	40	HC290	
12	Request received	160	Near azeotropic mixtures***	
13	Bjørn M. Larsen Gartneri	800	HC290	projecting
14	Request received	50	Near azeotropic mixture	
WASTE WATER BASED HEAT PUMPS				
15	TIMAR, Slørdal	585	NH_3	1987
16	Havbruksstasjonen, Tromsø	700	NH_3	1990
16	Request received	5500	NH_3	
ICERINKS				
17	Hamar Olympiahall	800	NH_3	1992
18	Hamar Ishall	375	NH_3	1992
19	Håkonshall, Lillehammer	650	NH_3	1992
INDUSTRIAL HEAT PUMPS				
120	Hallingdalsbruket, Torpo	600	NH_3	1991

* : Distribution at intermediate level
**: Rebuilding from CFC12 to NH_3
***: Distribution at low temperature

Bodø Airport (Korfitsen and Christensen 1992, Aaseth 1992). The Bodø Airport heat pump use ammonia as working fluid, and it is two staged. In order to handle high supply temperatures, the high pressure stage is equipped with 40 bar compressors.

The district heating system requires relatively high supply temperature in the distribution grid. The minimum temperature is defined by the house with the most outdated central heating system. This excludes the possibility to take advantage of modern low temperature heating systems in the new building stock. Further, modern and well insulated buildings often need summer cooling.

5.2.2. Distribution at intermediate level to the University in Bergen

At the University campus, there is a mix of old and new buildings. This requires another heat pump system than the solution chosen at the Bodø Airport. At the University, a central heat pump will deliver water with temperature 20-25 C on the coldest day to local heat pumps situated in different buildings at the campus. The central heat pump will use ammonia as working fluid.

Distribution at intermediate level will have several advantages compared to a traditional pipeline district heating and cooling system (Lorentzen and Nekså 1987). This plant will be the first of this type to be built in Norway. The concept has been considered for several other cases, for instance in a district heating and cooling system in a small city in the southern part of Norway.

Conclusions to be drawn after |0 years of operating heat pump P&D plants:

- good planning is necessary in order to have a successful installation
- the heat pump plant should be built as simple as possible
- low temperature level in the heat distribution grid makes it possible to have high COP and thereby better energy savings, besides the operating conditions of the heat pump becomes better
- sea water is the best low temperature heat source, and air is the second best
- the potential for heat pumps in single family houses is very large, but service routines are not good enough, resulting in expencive service

By dimensioning the heat pump to cover 50-60% of the load, it will cover 90% of the energy demand. In many cases, the energy savings will be high enough to cover the capital costs (see table 1, pay off time).

6. STRATEGY FOR THE 1993-96 PROGRAMME

The results for operation of the P&D plants show that the heat pump technology can contribute to a rational use of energy in Norway. The operation of the different P&D plant are well documented in different leaflets and brocheures that can be distributed to interested parties.

Problems that have to be solved in the future to take fully advantage of the heat pump technologies are linked to the replacement of CFCs, safe operation of heat pumps, and development of business based on heat pump technologies.

The strategy for the 1993-96 heat pump programme can be summarized as follows:

(1) energy conservation; implementation of heat pumps in market segments where they have an economic advantage to other technologies,

(2) environmental protection; removement of the negative effects from use of working fluids in heat pumps (i.e. replacement of CFCs)

(3) development of business; through development of products and services linked to a profitable and sage use of heat pump technologies.

REFERENCES

Eggen G. 1992. *Erfaringer fra Prototyp- og Demonstrasjonsanlegg for varmepumper.* SINTEF rapport STF11 A92017. Trondheim, Norway

Korfitsen E. and A. Christensen. 1992. "New Ammonia Technology for Heat Pumps". International Symposium on the 40th Anniversary of NTH Refrigeration Engineering June 22-24 1992, Trondheim, Norway, pp.165-177

Lystad T. 1991. *Arendal sentrum. Fordeling ved mellomtemperatur. Forprosjekt.* SINTEF rapport STF11 A91042. Trondheim, Norway.

Lorentzen G. and P. Nekså. 1987. "Large heat pump systems with distribution at intermediate temperature". Nordiske varmepumpedager, Reykjavik, Iceland.

Aaseth E. 1992. "Varmepumpe i fjernvarmeanlegg". Student's work Division of Refrigeration Engineering. NTH, Trondheim, Norway

Table 1. *Main data for heat pump P&D plants*

	Plant	HP-out-put (kW)	HP-energy prod. (MWh/ year)	Equivalent operating periode (h/year)	Forward /return temp. (°C/°C)	Sea-sonal COP HP (-)	COP incl. peak load. (-)	Pay off (years)	Specific investm. (NOK/ kW)
SEA WATER BASED HEAT PUMPS									
	Marintek, Sandefjord	90	550	6 100	50/40	2,5	2,4	4	550
	Favusgården, Harstad	120	600	5 000	43/35	3,5	3,0	3	500
	Ljones Gartneri, Har-danger	750	3 000	4 000	50/40	3,4	2,9	2	270
	Ålesund Tinghus	310	800	2 600	43/35	3,0	2,5	6	425
	Royal Garden Hotel	800	3 200	4 000	50/40	4,0	3,3	1,5	190
	Hadsel Folkehøgskole	200	700	3 500	70/60	2,9	2,5	5	440
	Gamvik kommune	300	1 500	5 000	60/50	3,0	2,5	5	670
	Polplast, Tromsø	70	122	1 750	50/40	2,1	2,1	-	105
	Hotel Maritim, Hauge-sund	310	1 000	3 230	70/60	2,9	2,9	1	125
	Fylkesbåtene i Sogn og Fjordane	45	195	4 330	45/35	3,2	3,2	5	690
	Protan, Haugesund	6 800	45 000	6 620	50/35	4,0	4,0	1	185
	Stokmarknes sykehus	400	2 300	5 750	70/60	2,7	2,0	3	530
	Widerøes Flyhangar	530	1 600	3 000	50/40	3,3	2,8	1	345
	VP-Fjernvarme, Ålesund Sentr.	6 000	27 000	4 500	90/60	3,5	2,4	-	560
GROUND COUPLED HEAT PUMPS									
	Jord/vann-VP, enebolig Heimdal	12	18	1 500	55/45	2,4		-	840
	Holmin Gartneri	250	1 000	4 000	55/45	3,3		2	210
	Nærvarmeanlegg, Mål-selv	52	207	4 000	55/45	2,7		-	1250
	Sagen, Kristiansand	50	212	4 200	55/45	2,7	2,4	-	1000
	Br. Myhre, Jevnaker	12	34	2 800	40/35	2,9	2,4	-	1040
	Søsterheimen B/L, Stord	18	66	3 700	55/45	2,3	2,2	20	1025

Table 1. *cont.*

	Plant	HP-out-put (kW)	HP-energy prod. (MWh/year)	Equivalent operating periode (h/year)	Forward /return temp. (°C/°C)	Sea-sonal COP HP (-)	COP incl. peak load. (-)	Pay off (years)	Spe-cific in-vest-m. (NOK/kW)
AIR BASED HEAT PUMPS									
	SINTEF Adm.bygg	130	410	3 150	80/45	2,5	2,3	15	810
	Felles luft/vann-VP, Heimdal	16	61	3 810	60/50	2,5	1,9	-	1175
	Luft/luft-VP, enebolig Heimdal	3,5	11	3 150	-	2,4	2,0	15	1075
	Luft/luft-VP, enebolig Heimdal	4,5	12	2 700	-	2,4	2,2	15	840
	Avtrekksluft VP, varmt-vannsber.	1	4	4 000	(50)	2,4		8	1250
	Varmeveksler + VP, varmtv.ber.	1	4	4 000	(50)	2,2		17	1500
	Grude Gartneri	45	180	4 000	-	3,0	1,9	4	415
	Dalaker Gartneri	108	410	3 800	-	3,0	1,5	2,5	260
	Medhus Gartneri	28	142	5 070	30/20	3,9		2	230
	Gruben vegstasjon	56	175	3130	50/40	2,6	2,1	15	835
	Mosjøen vegstasjon	90	360	4 000	-	2,5	2,3	14	990
	Luft/luft-VP, enebolig Askim	4,7	19	4 000	-	2,4	1,9	5	940
	Alexandra Hotel	400	2 000	5 000	54/45	2,9		2	440
	Bjørnheim B/L, Oslo	65	350	5 400	(55)	2,5	1,7	9	1625
WASTE WATER BASED HEAT PUMPS									
	Skøyen Vest	2 200	12 000	5 500	90/60	3,0		-	-
	Sandvika Sentrum	13 000	65 000	5 000	90/60	3,8	3,1	10	-
	Industriarbeidermuseet, Rjukan	240	820	3 400	45/35	5,6	4,6	7	760
	Matre Akva	490	1 925	4 000	-	6,6		1	140
	TIMAR, Slørdal	585	1 670	2 900	-	7,7		1,5	190
	Midt-Finnmark Smolt	390	780	2 000		5,8		3	250