Chapter 42

Estimating International Heat Pump Use

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ABSTRACT: International heat pump use has grown nearly sevenfold in the last decade. 3.8 million units were installed in 1985, the majority for residential space heating or space heating and cooling, and this quantity is still increasing. Usage for commercial, institutional, and industrial space conditioning is also expanding, as it is for water heating, swimming pool heating and dehumidification, industrial process heating and drying, and district heating. Greatest application is in the highly industrialized and developed countries, particularly those where building air conditioning is common such as Japan and the United States. The trend for space heating is radically different in Europe, where the newer heat pump market is rapidly declining. Uncertainties regarding future energy prices and policies impact heat pump use; the market reaction, most noticeably in Europe, reflects a gamble on low oil prices in the future.

INTRODUCTION

Falling oil, and consequently gas, prices are generally perceived as weakening the near-term market for heat pumps. Compounding this situation, in many countries, are both rising electrical rates and changing policies regarding heat pump promotion; the latter are primarily attributable to governmental reactions to recent nuclear power incidents and the former to new plant amortization. Accurate data and understanding are therefore needed by governmental policy makers, utility planners, and the manufacturing and construction industries to gauge the market impact, identify opportunities, and improve preparations and predictions for the future.

This paper presents the preliminary findings of an attempt to estimate the size and trends of the international heat pump market. Also addressed are the data sources and difficulties encountered to date. A future publication will present a more complete analysis as further data are obtained.

HEAT PUMPS: Prospects in Heat Pump Technology and Marketing (Proceedings of the 1987 IEA Heat Pump Conference). Edited by Kay H. Zimmerman

DATA COLLECTION

The types of data available from individual countries depend on the entity that performs the collection and, not surprisingly, vary considerably. Among the sources of heat pump statistics are:

Recurring census surveys,
One-time or recurring commerce surveys by government agencies,
Manufacturer trade association statistics programs,
Installer trade association statistics programs,
Builder trade association surveys,
Utility trade or research association studies,
One-time or recurring analyses of utility files,
Published and unpublished research surveys, and
Expert estimates.

For the countries examined, every comparison of data from multiple — but independent — sources (the references provide a partial list) yielded conflicting statistics even with, where possible, adjustments for exports and/or imports. Further, although a lesser concern, little consistency exists among the countries or sources for the classification of data. For example, manufacturers and their trade associations tend to categorize statistics by product configurations and capacities. Installers and their trade associations refer, instead, to application characteristics. Builders naturally refer to the type of construction. Utilities generally report statistics only for equipment using the energy form (i.e., electricity or gas) provided and then only within their own service areas.

Some of the differences in data can be attributed to errors in extrapolation from survey samples or from limited service area records to national statistics. In other cases, particularly when multiple trade associations are involved, some conflicts

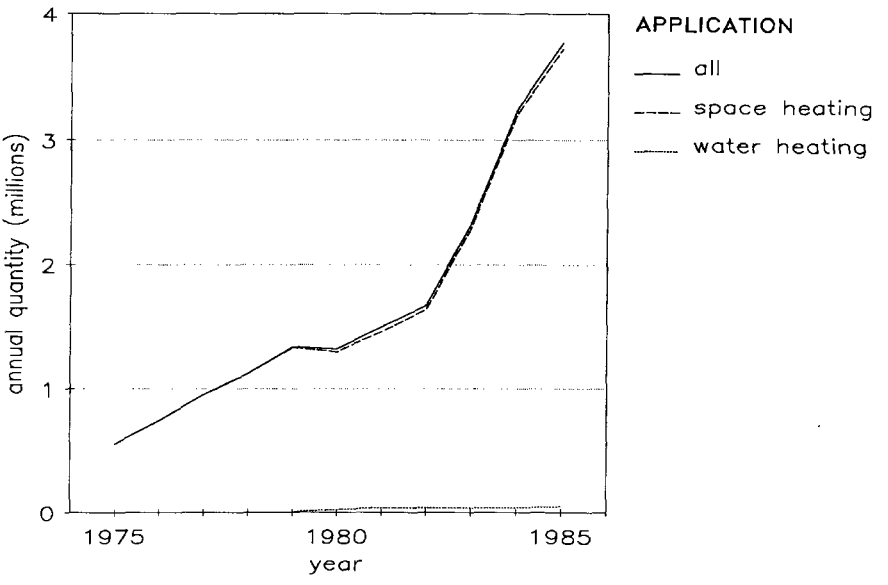

Figure 1. International heat pump use (preliminary data)

result from disparity in membership, often with none of the reporting associations representing all of the firms actually involved.

PRELIMINARY FINDINGS

International heat pump use has, with the exception of 1980, increased fairly steadily for more than a decade as shown in Figure 1. The aberrant year followed the second international oil-price shock, but a more plausible explanation is general economic recession with growth following 1980 — due to the inertial lag — resulting from the impacts of the 1979 price jolt.

Space heating heat pumps clearly dominate the the market.

Space Heating

For Canada, Japan, and the United States, the most common heat pump for space heating is the air-to-air, dual-mode (heating and cooling), electric heat pump. The majority of units in these countries are unitary (consisting of one or more units or modules designed to be used together without specific application engineering) split systems (having a remote outdoor unit connected to the indoor unit via refrigerant lines). These heat pumps are generally monovalent, using electric-resistance heat for supplemental and/or backup needs.

Air-to-water, heating-only heat pumps are the most common type for the European countries. Electric-motor drives are, again, the most common, although a smaller market exists for gas-engine-driven, and to a lesser extent for diesel-driven, heat pumps. By contrast to Canada, Japan, and the United States, the

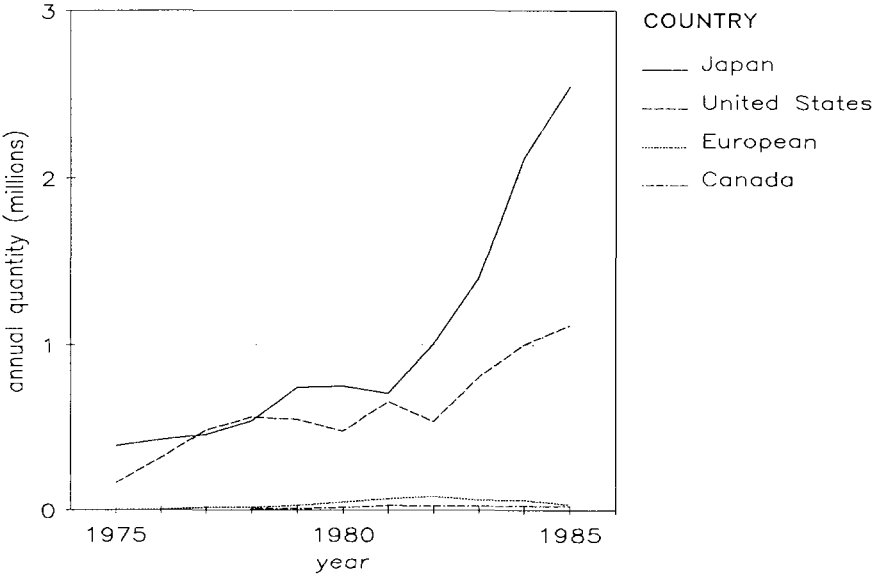

Figure 2. Heat pumps for space heating (preliminary data)

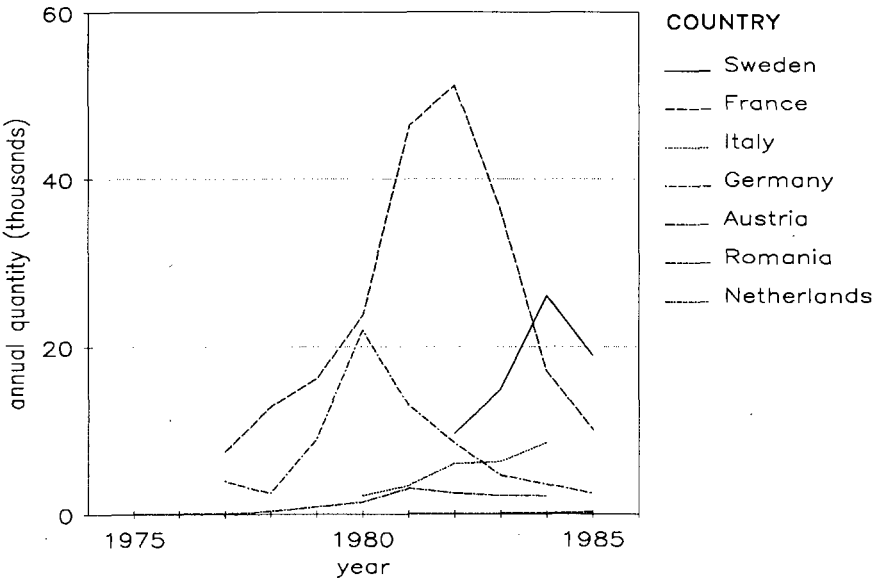

Figure 3. Heat pumps for space heating in Europe (preliminary data)

typical European heat pump is bivalent (using a combustion-based system, such as an oil- or gas-fired boiler or furnace, for peak and backup heating).

Figure 2 contrasts heat pump use for space heating in Japan, the United States, and Canada — sometimes referred to as *the Pacific countries* in international heat pump discussions — with that of the European countries. The sheer quantities of heat pumps in Japan and the U.S. overwhelm those in the rest of the world.

The European situation is elaborated, on an expanded ordinate, in Figure 3. Except for Austria, Italy, and Romania (discussed individually below), the characteristic market in the European countries with known data has been rapid growth followed by precipitous decline. Differences in the timing (for example, the rapid market increase in Sweden began long after the collapse of the German market and the respective peaks were separated by four years), strength, and duration of this pattern can be answered by differences in national energy prices and heat pump promotional incentives.

Water Heating

The heat pump market for service, including domestic, water heating is relatively small (see Figure 1) in comparison to that for space heating. It is, however, somewhat younger and — at least until 1986 — growing even in Europe (see Figure 4). The typical heat pump is an electric-powered air-to-water unit. High annual load factors result in better economic viability, in many cases, than for space heating. A limited number of integrated space and water heating heat pumps are sold, but their market is estimated to be relatively small; substantiating data have not been identified.

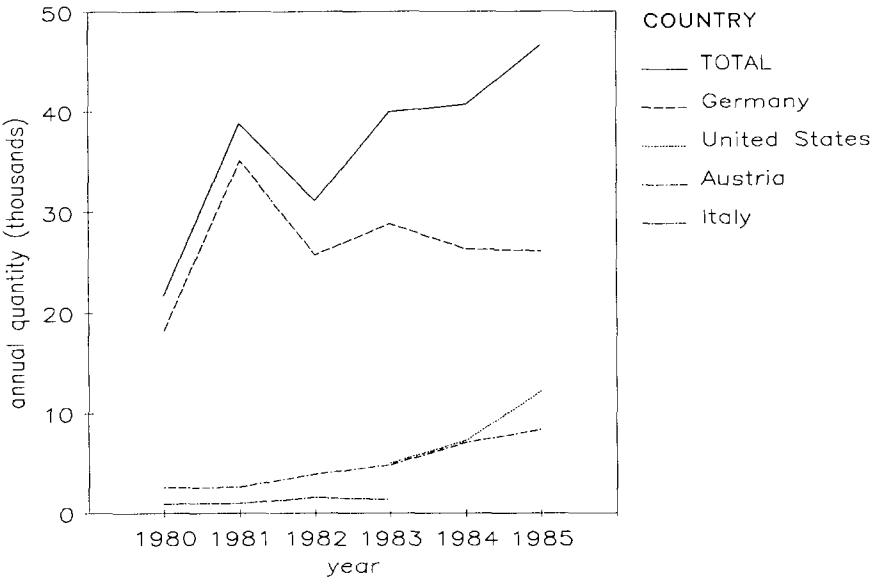

Figure 4. Heat pumps for water heating (preliminary data)

Pool Heating

Heating of swimming pools is a very favorable application of heat pumps, owing both to the high performance levels achieved at the moderate supply temperatures and, for indoor pools, to the inevitable need for concurrent dehumidification. The market for these devices is estimated to be growing and is already well established in Europe, where the first such application was completed in 1939.

Industrial Heating

The available data on the heat pump market for process heating is too limited for accurate depiction in Figure 1. Also, while the quantities involved are small compared to those for space heating, their average capacity is much larger. On bases of thermal capacity, financial value, or energy savings, the industrial heat pump market is quite significant.

Use of both open- and closed-cycle heat pumps is believed to be growing, although the former has a larger market size at present. Process heating is the only market in which absorption heat pumps (specifically excluding cooling-only devices) as well as heat transformers (sometimes referred to as type II heat pumps) have proven economic viability.

District Heating

Exploited most heavily in Sweden, heat pumps have also been applied to lesser extents for district heating in the other Nordic countries and Romania. Small

numbers of installations have been made in France, the Federal Republic of Germany, the German Democratic Republic, Liechtenstein, the Netherlands, Switzerland, and the Soviet Union. Several installations of heat pumps for district heating and cooling also exist in Japan and the United States. The economics of these systems have generally been rather attractive.

DIVERSE NATIONAL MARKET PROFILES

The heat pump market complexion varies considerably among the countries for which data have been identified. The following profiles summarize the information obtained. Inclusion or exclusion of specific countries signifies only the availability of data and in no case implies any system of preferences or ranking.

Austria [1-5]

Austria claims the first heat pump installation, an open-cycle industrial system installed in a salt works in Ebensee in 1856 [3].

Heat pump sales for space heating have been nearly constant at approximately 2000 units/year, mostly air-source. Use of heat pump water heaters has grown steadily, reaching 8,400 units in 1985; two-thirds of these machines are produced domestically.

Interest is growing in ground-source systems, both direct expansion and ground-coupled, with a variety of heat exchanger designs. The feasibility of using large heat pumps in district heating is being evaluated for at least two systems.

Canada [6-7]

Cumulative sales of heat pumps in Canada for 1975-1985 are estimated at 100,000 units, of which approximately 60% are installed in the province of Ontario. Use of industrial heat pumps is limited, with approximately 15 existing medium and large installations. Heat pumps are accepted as the preferred means for and are used in approximately half of the hardwood dryers in Ontario.

Denmark [8]

The space heating market reached its maximum in 1981-1983 with approximately 2,000 small heat pumps. It has subsequently decreased to several hundred units per year. Total installations through 1985 are estimated at 8,000, of which nearly 50% are of the air-to-water type. Approximately 20,000 air-source heat pump water heaters are in use, with several domestic firms manufacturing exhaust-air heat reclaim heat pumps for single-family residences. Approximately 50 medium- and large-sized heat pumps are in use for district heating and other industrial uses.

Finland [9]

Still affected by an unsuccessful thrust into heat pump production in the 1970s, the market for heat pumps in Finland is rather limited. Approximately 5,000 units, mainly ground-source, were installed, but withdrawal or bankruptcy of most of the small manufacturers involved left these units without support for further

maintenance. Six heat pumps, with a combined thermal capacity of 36 MW, are in use for district heating.

France [10-13]

The theoretical concept of a heat pump, thermodynamically a reverse heat engine cycle, originated in France in 1824 in a treatise by Sadi Carnot.

As shown in Figure 2, France has had the largest market for heat pumps in Europe, but this market has been declining since 1982 when it exceeded 50,000 units/year, far short of an initially targeted market of more than 100,000 heat pumps per year. 1985 use is estimated at 10,000 units.

Several hundred heat pumps are in use in the 50-500 kw_t range for multifamily-residential and commercial buildings.

Approximately 15 heat pumps are used in agricultural applications. In the industrial sector, use grew from approximately 500 heat pumps in 1979 to nearly 1,200 in 1982 (later data are unavailable, but the market is believed to have declined); many of these units were, however, for space heating of industrial facilities. Low-temperature drying remains an attractive market for heat pumps.

Germany [14-18]

The Federal Republic of Germany has the largest stock of gas-engine drive heat pumps with more than 700 operating units. The market for these machines has, however, sharply declined in the last two to three years.

The German heat pump market peaked in 1980 with nearly 22,000 electric-powered units for space heating and in 1981 with nearly 39,000 units for water heating. The latter application continues with more than 26,000 units in 1985, but the former has declined to approximately one-tenth of the cited peak (see Figures 3 and 4). German heat pump water heater sales are the highest in the world.

Italy [19-21]

Somewhat unique for Europe, Italian heat pumps derive from air conditioning designs. Most of the installed machines are, therefore, air-source and air is more common than hot water for distribution.

The market for space heating heat pumps nearly tripled from 3,100 units in 1980 to 8,600 in 1984, but more recent data have not been obtained. The water heating market peaked in 1982 with 1,500 heat pumps, but data are unavailable beyond 1983.

A small number of imported engine-driven and a few experimental absorption heat pumps are in operation.

Japan [22-27]

In quantities of heat pumps, Japan[1] has the largest market in the world as can be seen in Figure 2. Small ductless air-to-air units, referred to as *room air conditioner (RAC) heat pumps*, with capacities up to 3 kW_t dominate the market.

[1] Japanese annual data reflect the period from the beginning of October to end of the following September (e.g., 1985 data are for October 1984 through September 1985). The data for other countries are for the calendar year.

Available in window and through-the-wall configurations as well as in split systems, both single- and multizone, 1985 domestic sales were nearly 2.2 million heat pumps. Approximately 0.4 million additional heat pumps in larger sizes, termed *commercial air conditioner heat pumps* and *water chiller heat pumps*, were also sold. Virtually all of these units are dual mode (heating and cooling). Strong growth is expected in the near term market, influenced to a large measure by innovative room heat pumps incorporating inverters, scroll compressors, in-floor condensers, and even nonazeotropic mixture refrigerants with charge composition control for operation optimization.

Industrial heat pumps, including absorption type, also are used with 1985 installations amounting to an estimated 6 MW_e.

Netherlands [28-29]

The Netherlands are believed to employ the highest fraction of gas-engine-driven heat pumps in the world. Owing to large natural gas resources, a highly developed gas distribution infrastructure, and relatively high electric-to-gas price ratios, gas is the dominant heating fuel. The majority of heat pumps use air as the heat source with surface water a close second (nearly 40%). The total installed capacity of heat pumps exceeds 40 MW_t, including approximately 90 engine-driven (most with capacities exceeding 100 kW_t), 4 absorption, and 40-50 electric-motor powered heat pumps.

Norway [30]

The energy situation in Norway is envied by most other countries; in addition to very large, producing oil fields, the nation's electrical generation is — except in abnormally dry years for which thermal generating plants are in reserve — practically entirely by hydroelectric power. The consequently low prices for energy, compounded by relatively high interest rates, have resulted in less favorable economics for heat pumps than in other Scandinavian countries. Residential use, single- and multifamily, is very limited. However, approximately 120 installations have been made in greenhouses and another 100-150 for fish hatcheries, some with capacities exceeding 750 kW_t. 40 heat pumps are in use for fish drying and an estimated 200 for lumber drying. Open-cycle systems, with coefficients of performance as high as 30, have been used for concentration of liquids for more than 50 years. Domestic heat pump water heaters are rare, but one 6.5 MW_t water heater is in use in an alginate plant.

Romania [31]

Although small heat pumps are not used, Romania is the leading country in application of absorption heat pumps in district heating. The largest known resorption heat pump in the world, 8.7 MW_t using an ammonia/water solution, was installed in Bucharest in 1984. Steam-powered lithium bromide/water absorption cycles have been used since 1983, including 10 heat pumps of 2.2 MW_t and 15 of 5.8 MW_t.

Installations of smaller heat pumps, mainly for space and process heating, have increased from 90 units in 1983 to 200 in 1985 with capacities ranging from 30 to 230 kW_t. The heat sources used are primarily cooling water from transformers and compressors, industrial waste heat, and groundwater. A 7.3 MW_t vapor-

compression heat pump, using a centrifugal compressor, is under construction for district heating.

Sweden [32-36]

Swedish use of large heat pumps in district heating is unmatched elsewhere, with at least four operating plants producing more than 100 MW_t each; the biggest, Stockholm Ropsten, uses six 25 MW_t machines. The largest individual heat pump, located in Göteborg, has a capacity of 45 MW_t,[2] employing a three-stage centrifugal compressor driven by an electric motor; it uses treated sewage effluent as its heat-source. Approximately 100 heat pumps with capacities exceeding 1 MW_t are in use. A single absorption machine of 7 MW_t capacity is also in operation for district heating.

The market for smaller machines peaked in 1984 with more than 26,000 units, mostly using outside-air and exhaust-air systems; nearly 8,000 of the latter were installed in 1984 and again in 1985. Ground-source (referred to as *bedrock*) heat pump systems, both ground-coupled and direct expansion, are also widely used.

United Kingdom [37-38]

Although both the first proposal for use of heat pumps for space heating, by Lord Kelvin in 1852, and the first such application, by T. G. N. Haldane in 1924, were in the UK, the market for such devices is limited. The present installation level is several hundred units per annum, equivalent to approximately 50 MW_e, with the majority being imported. Application in commercial buildings, particularly in stores, pubs, and facilities requiring air conditioning, is increasing, primarily with use of air-to-air packaged units. Heat pump use for swimming pools is also growing and represents a larger than anticipated market.

While the numbers of heat pumps used in various applications have not been identified, the financial value of installed equipment has increased rapidly with the both the highest share and gain being for air-to-air heat pumps. A 1984 survey projected a doubling of the heat pump market within 5 years.

United States [39-44]

The first commercialization of heat pumps for space heating began in the United States, which in aggregate heating capacities has the highest amounts of both existing and new heat pumps in the world. In terms of quantities, the U.S. follows Japan as shown in Figure 2.

Introduced in the early 1930's, heat pumps are now used to heat, or more commonly to heat and cool, approximately 30% of all new building in the United States. Their use is generally lower for domestic water and industrial process heating, and is still at the pioneering stage for district heating and cooling. Heat pump sales, as shown in Figures 2 and 4, have generally increased for the last decade and have established successive record levels in each of the last three years.

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[2] Capacity ratings of large heat pumps are somewhat nebulous since each such machine is uniquely designed and operated with varying conditions. The unit cited, for example, has eight operating modes ranging from 25 to 45 MW_t capacity.

Continuation of this trend[3] is expected in 1986 for space heating devices, but a sharp decline is likely for heat pump water heaters.

Aggregate sales in 1985 are estimated to exceed 1.1 million units, including more than 12,000 for water heating and approximately 5,000 for process use. Note that a much larger market exists for cooling-only or cooling-controlled air-conditioning devices

CONTINUATION

As indicated above, findings reported herein should be regarded as preliminary. Data collection will continue, with emphasis on obtaining more complete information and resolving the conflicts cited. Any assistance that can be provided in this regard would be welcome; data or suggestions should be sent to: James M. Calm, IEA Heat Pump Center, FIZ-Karlsruhe, D-7514 Eggenstein-Leopoldshafen 2, Federal Republic of Germany.

SUMMARY

With the exception of 1980, ironically immediately following the second international oil shock, heat pump use has consistently expanded in each year of the last decade; it has increased nearly sevenfold in that period. The majority of use is for residential space heating or space heating and cooling. It appears that usage for commercial, institutional, and industrial space conditioning as well as for water heating, swimming pool heating and dehumidification, industrial process heating and drying, and district heating is also growing. Greatest use is in the highly industrialized and developed countries, particularly those where building air conditioning is common such as Japan and the United States.

The overall picture is radically different in Europe, where the much newer market is rapidly declining. Exceptions are for applications other than space conditioning and, to a limited extent, for building heating where air conditioning is emerging.

Uncertainties regarding future energy prices and electric generation, particularly nuclear, impact heat pump use. The market reaction, most noticeably in Europe, reflects a gamble on low oil prices in the future.

The availability, consistency, and completeness of market data for heat pumps and their use is insufficient, and the results presented in this continuing study should necessarily be regarded as preliminary.

ACKNOWLEDGEMENTS

This work is an extension of market data collection and analysis begun by A. Mitchell and J. A. Corfee, both formerly with the IEA Heat Pump Center (HPC),

[3] Although the quantity of new heat pump installations is increasing in single-family residential construction, the penetration rate is likely to have decreased in 1986 for the first time since 1979 (actual data will be unavailable until the summer of 1987). Both the absolute quantity and penetration rate decreased in multifamily-residential construction in 1985 and continuation is expected. For commercial and institutional construction, installation quantities have been increasing while penetration has declined slightly. Although highly speculative, penetration growth is likely to resume following 1987 when electricity/gas price ratios are projected to decline again.

under the leadership of K. O. Holzapfel [45]. Assisting with data gathering in the member countries of the HPC are the national teams including, to date, P. V. Gilli and R. Brandner (Austria), I. R. G. Lowe (Canada), K. O. Holzapfel (FRG), F. Trombetti (Italy), E. Miura (Japan), J. A. W. Oldenhof (The Netherlands), B. Lundqvist (Sweden), and F. A. Creswick and K. H. Zimmerman (USA).

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