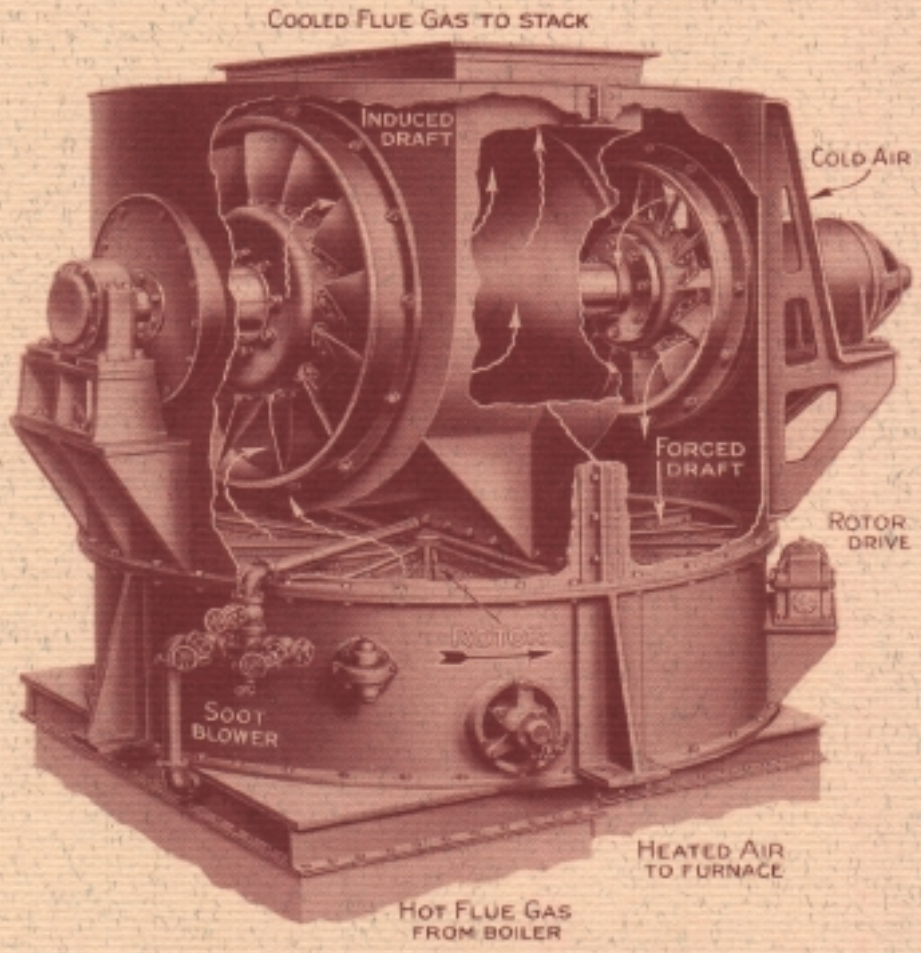
Ljungström®

The Ljungström Air Preheater 1920

An International Historic Mechanical Engineering Landmark



June 21, 1995
Stockholm, Sweden

SMR
Svenska Mekanisters Riksförening

American Society of Mechanical Engineers

Stockholm 1920
The Ljungström Air Preheater

The inventor Fredrik Ljungström from the Ljungström Medal

Historical Significance of Landmark

Throughout the history of boilers there have been many advancements in order to obtain a better performance and lower fuel consumption. However, few inventions have been as successful in saving fuel as the Ljungström Air Preheater invented by Fredrik Ljungström, then Technical Director at Aktiebolaget Ljungström Ångturbin (ALÅ). The first installation in a commercial boiler saved as much as 25% of the fuel consumption. In a modern utility boiler the Ljungström Air Preheater provides up to 20% of the total heat transfer in the boiler process, but the Ljungström Air Preheater only represents 2% of the investment.

The Ljungström Air Preheater is a remarkable invention in many ways. About 20,000 had been supplied to all corners of the globe by 1994. It has been estimated that the total operating hours amassed by all Ljungström Air Preheaters amount to about 1,500,000,000.

The earliest installations of the Ljungström Air Preheater have been taken out of service because the fact that the boiler plants have been torn down, consequently the ASME International Historic Mechanical Engineering Landmark is placed at Tekniska Museet in Stockholm with a permanent exhibition comprising a working model earlier used for experiments 1961 - 77 at Svenska Rotor Maskiner AB.

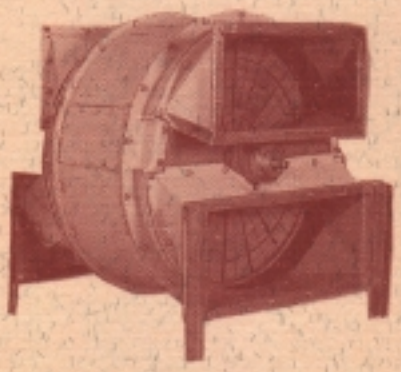


Figure 1. *The landmarked model of the Ljungström Air Preheater at Tekniska Museet, Stockholm.*

Economic Impact of the Landmark

The use of a Ljungström Air Preheater in a modern boiler plant saves a considerable quantity of fuel - so much that the cost of the preheater is generally recovered after only a few months. It has been estimated that the total world-wide fuel savings resulting from all Ljungström Air Preheaters which have been in service is equivalent to 4,500,000,000 tonnes (4,960,000,000 tons) of oil. An estimate shows that the Ljungström Air Preheaters in operation annually saves about $30 Billion US. The distribution of thermal power capacity in which Ljungström Air Preheaters are installed over the world is shown in the table below. The estimated distribution of annual saving in $US can also be found in the table below:

Continent	Installed capacity GW	%	Saving $BUS/year
Africa	65	5	1.6
North America	471	30	6.6
South America	35	2	0.7
Asia	370	24	7.7
CIS	216	14	3.8
Europe	365	23	7.6
Oceania	38	2	0.5
TOTAL	1560	100	28.5

Landmark Contribution to Development of New World Wide Industry

The use of the Ljungström Air Preheater started in the 1920:s throughout the whole world. In the beginning the marketing of the Ljungström Air Preheater was made in close connection with ALÅ, but most of the deliveries have actually been made through a network of licensees throughout the world.

Licensees

1923 Svenska Maskinverken AB, Sweden
James Howden & Co., G:t Britain*
Maskin & Brobyggnad, Finland
1924 Smulders, Belgium*
Nebrich, Czechoslovakia
Gefia, Austria
1925 Oekonomia/Ganz, Hungary*
Feuerungstechnik, Germany
Lammers & Maase, Germany
1926 Air Preheater Company, USA*
1927 Gadelius, Japan*
Babcock & Wilcox, France*
1930 Luftvorwärmer, Germany
Sulzer, Switzerland
1932 Hueck & Büren, Germany
Julius Pinsch, Germany
1933 Wiesner, Czechoslovakia
1934 Kraftanlagen Heidelberg, Germany*
1935 Dano, Denmark
Skoda, Czechoslovakia
Witkowitz, Czechoslovakia
Cegielski, Poland
1936 Simmering, Austria*
1937 Erste Brünner, Czechoslovakia*
Ceskomoravska, Czechoslovakia
1942 Venezia, Italy*
Holima, the Netherlands*
Breda, Italy*
1943 Ansaldo, Italy*
1947 Tosi, Italy*
1949 Gefia, Genua, Italy
1952 Tampella, Finland
1957 Ganz, Hungary*
1958 Burmeister & Wain, Denmark
1959 Rafako, Poland*
1967 Stein, France*

* Still licensee of SRM

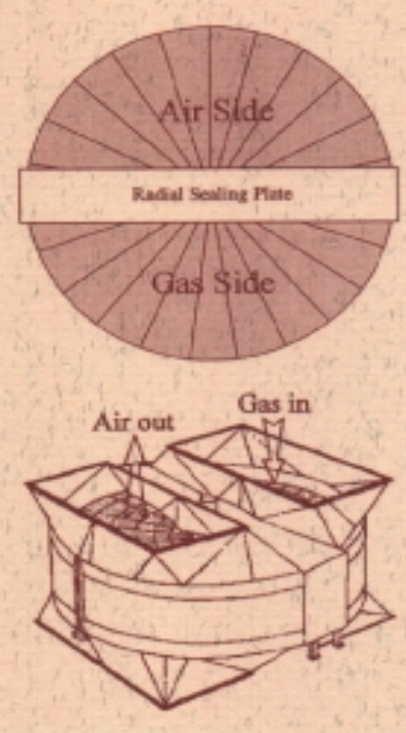


Figure 2. *Principles of the Ljungström Air Preheate*

Ljungström Air Preheaters are used primarily in boiler plants for preheating the combustion air. In recent years, their use has expanded to include energy recovery in combination with removal of oxides of sulphur and nitrogen from flue gases sometimes using catalyst coated heating element plates.

Special Features and Characteristics

The Ljungström Air Preheater is a regenerative heat exchanger, and comprises a slowly rotating rotor filled with heat transfer plates. The hot and cold gas ducts are arranged so that half of the rotor is in the flue gas duct and the other half is in the primary air duct which supplies combustion air to the furnace. The hot flue gases heat the part of the rotor in their path, and as the rotor rotates, the hot section moves into the path of the combustion air and preheats it. The rotor is divided into a number of sections which pass through seals in order to prevent the flue gases and the combustion air from mixing.

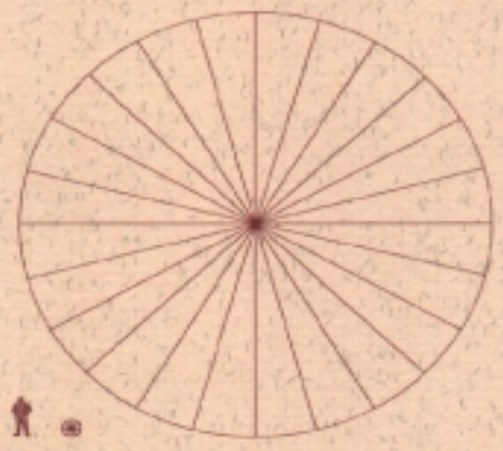


Figure 3. *Span of sizes for Ljungström Air Preheaters, from 0.8 to over 20 m diameter (2.5 to 66 ft)*

A rotor in a Ljungström Air Preheater may be over 20m (66ft) in diameter and up to a couple of metres (8ft) thick. The total weight of such a rotor may be up to 1,000 tonnes (1,100 tons). The flue gases normally enter the rotor at a temperature of about 350 °C (660 °F), and are cooled to about 120 °C (250 °F) in flowing through it. These temperatures may vary somewhat, depending on the type of fuel. Gas flow rates through the largest preheaters are of the order of 2 million Nm^3/h (70 million standard ft^3/hr) on each side, and the temperature effectiveness, the quotient between the temperature drop of one side and the maximal available temperature difference, is typically 85%. An advantage of the Ljungström method over other methods is that the temperature of the flue gases can be reduced below the sulphuric acid dew point without causing problems. In a recuperative heat exchanger, in which the heat flows through a separating wall, the efficiency falls off rapidly if the temperature is reduced below the dew point, as deposits form on the heat transfer surfaces and act as a thermal barrier. On the other hand, deposits on the surfaces of a Ljungström Air Preheater have no measurable effect on heat transfer performance.

A Ljungström Air Preheater is also relatively insensitive to corrosion. Any parts that do corrode away can be easily replaced at a modest cost, and leakage of air to the flue gas side is not affected by corrosion of the heat transfer plates.

Historical Development

The brothers Birger and Fredrik Ljungström founded Aktiebolaget Ljungström Ångturbin (ALÅ) on February 29, 1908 for development of the double rotating steam turbine. The manufacture of this invention was made in Finspång at the subsidiary Svenska Turbinaktiebolaget Ljungström (STAL). ASEA took over STAL in 1916 from ALÅ, while the development and the manufacture of turbine-powered locomotives was started at Gåshaga on the island of Lidingö nearby Stockholm. During a dinner at the Operakällaren Restaurant in Stockholm, Fredrik Ljungström, who suffered from asthma, was bothered by the dense clouds of cigar smoke and started to wonder how it might be possible to improve the ventilation without losing heat. Using his own idea from 1895 with corrugated heat exchanger elements applied in a high pressure steam boiler resulted in the idea of the regenerative heat exchanger, and the Ljungström Air Preheater was born. The first tests were performed in ALÅ's facilities at Gåshaga with paper as heating elements. The first prototype preheater was then later installed at the factory boiler at Gåshaga.

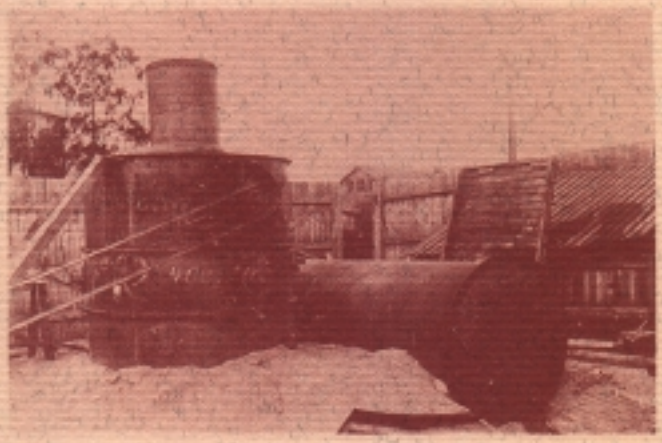


Figure 4. *The first prototype of the Ljungström Air Preheater at Gåshaga*

The first commercial installation of the Ljungström Air Preheater was made in 1922 for AB Förenade Choklad Fabrikerna (a chocolate manufacturer) on the island of Kungsholmen in Stockholm.


AKTIEBOLAGET
LJUNGSTRÖMS ÅNGTURBIN
STOCKHOLM
SWEDEN
25% FUEL SAVING.

Figure 5. *Report from performance measurements at AB Förenade Choklad Fabrikerna. (United Chocolate Factories)*

Technical Data for the Coal Fired Grate Boiler

Data for the hand fired boiler before and after the installation of Ljungström Air Preheater is as follows:

	Before	After
Calorific value of coal	6940	7020
Date of measurement	1922-03-20	1922-03-21
Fuel consumption (kg/h)	350	288
Water evaporated (kg/h)	2100	2180
Average Steam Temperature (C°)	330.7	330
Average Steam Pressure (kg/m²)	9.8	9.9
Feed water temperature (C°)	4.,5	4.5
Gas temperature in (C°)		322
Gas temperature out (C°)	330	166
Air temperature in (C°)		40
Air temperature out (C°)		238
Effectiveness, air side (%)		70.2
Effectiveness, gas side (%)		55.3
Thermal efficiency of boiler	59.3	74.3

After the first successful installations of the Ljungström Air Preheater, it was introduced on the market world-wide as a means of saving fuel in boilers. This was very successful, in spite of the fact that many boilers had to be modified to operate with the higher combustion air temperatures. Boilers at that time were not normally fitted with induced draught fans, so the fans were incorporated in the air preheaters. A picture of this arrangement is shown on the cover.

Some of the steam-turbine powered locomotives manufactured by the company were also fitted with Ljungström Air Preheaters at the front in order to increase efficiency.

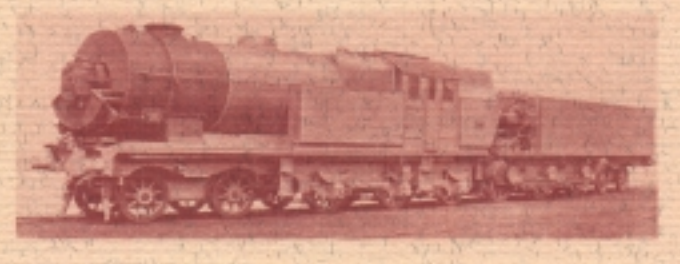


Figure 6. *The Ljungström locomotive with a Ljungström Air Preheater mounted at the front*

Typical Data for today's sizes of Ljungström Air Preheater

The sizes of boilers have since then increased and below typical data for a modern installation is:

Boiler Size (electrical output)	300 MW	500 MW
Fuel	Coal	Oil
Ljungström Air Preheater Size	2 x 28.5	2 x 30
Diameter (m)	9.9	1 1.4
Area (m²)	7 3	9 7
Height(m)	2.0	1.8
Rotation speed (rpm)	2	2
Gas flow (Nm³/h)	450 000	610 000
Air flow (Nm³/h)	430 000	575 000
Gas temperature in (C°)	375	375
Gas temperature out (C°)	120	140
Air temperature in (C°)	3 5	50
Air temperature out (C°)	325	324
Effectiveness, air side (%)	85.4	84.2
Effectiveness, gas side (%)	74.9	72. 5

Ljungström Gas Heater

The growing pressure reduce emissions from boilers has resulted in considerable interest in new versions of the Ljungström Heat Exchanger. One of these applications is in connection with desulphurisation. The process involves washing the flue gases in a slurry of water and limestone particles in scrubbers in order to make the sulphur oxides to react with the slurry. This process cools the gas down to about 50 symbol 176 \f “Symbol” \s 10C (120 symbol 176 \f “Symbol” \s 10F), The gases are then reheated so that they have sufficient buoyancy to rise and disperse in the higher layers of the atmosphere.

A regenerative heat exchanger of the Ljungström type, the Ljungström Gas Heater, is highly suitable for this purpose. Gas temperatures are in the 50 - 130 °C (120 - 265 symbol 176 \f “Symbol” \s 10F) range, i.e. at a temperature at which sulphuric acid condenses on the heat exchanger surfaces. Corrosion problems are overcome by using new types of materials such as plastic for the heating elements and coatings of the housing by glass flake lining.

This method of recovery was first employed 1976 in Japan, as the Japanese were quick to introduce strict anti-pollution legislation for their power stations. The first European installation of this type ws made in 1981 at Wilhelmshaven on the North Sea coast of Germany. Two Ljungström Gas Heaters with a diameter of 15 m (48 ft) reheat a total gas flow of 2.8 million Nm³/h (100 million standard ft³/hr).

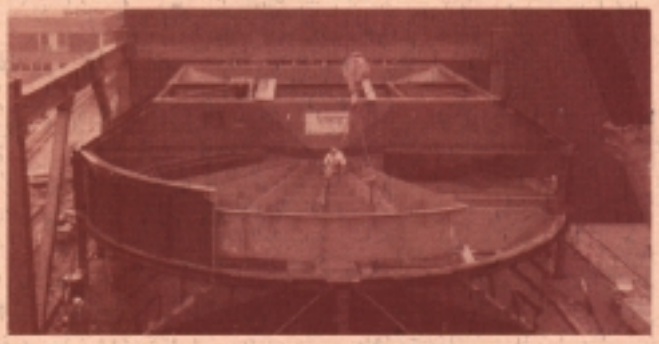


Figure 7. *Erection of the Ljungström Gas Heater in Wilhelmshaven*

By the beginning of 1994, experience from about 80 Ljungström Gas Heaters showed that this technology could be regarded as technically mature.

Ljungström, Gas Heaters are also used in denitrification plants, and particularly in those involving catalytic reduction of the oxides of nitrogen. Temperatures in these plants are about the same as those in air preheaters. However, a new problem occurs: clogging of the preheater by the ammonium bisulphate formed in the reduction process. This problem is overcome by improved soot blowing methods and new types of on-line water cleaning.

Ljungström Catalyst Air Preheater

Another idea which is admittedly not new - SRM holds patents on it dating back to the 1950's - but which is attractive from every angle, is to employ catalytically active materials on the rotor plates of the preheater. This allows the reduction process for the oxides of nitrogen, for example, to take place in the air preheater itself. An advantage of this is that it is necessary only to replace the rotor plates and to fit the necessary additional equipment for the injection of ammonia. The alternative in many cases involves building new gas ducts and installing a stationary matrix of catalyst elements, which can be expensive and difficult to accommodate in an existing boiler plant.

In order to effect the catalytic reaction on the existing, available surface area of a preheater and to ensure reliable operation at the temperatures involved, the catalysts used must be very active at these temperatures and must be insensitive to the pollutants likely to occur. This has been a very delicate technical problem to solve. The first commercial installation of a Ljungström Catalyst Air Preheater for denitrification was made in 1990 at the natural gas fired Mandalay Power Station in California, USA, by SRM licensee Kraftanlagen AG, Germany.

Historical events

1895 The inventor Fredrik Ljungström is born.
1908 AB Ljungströms Ångturbin (ALÅ) is founded on February 29.
1920 Fredrik Ljungström designs the first Ljungström Air Preheater. Tests at laboratories at Gåshaga with a paper model. The first Letter Patent is granted in Sweden.
1921 Installation of a prototype in the factory at Gåshaga, Lidingö. The result is 16% less fuel consumption - a technical breakthrough.
1922 Installation in Förenade Choklad Fabrikerna, Stockholm. The result is 25% less fuel consumption. Installation in Holmens Bruk, Sweden. The first licences are signed with Svenska Maskinverken, Sweden, and J. Howden, Scotland. Technical problems occur, the grate disappears and the brick walls in the boiler fall down due to the increased temperature in boiler preheated air.
1923 Installation in the Turbine Locomotive. A joint venture ALÅ and J. Howden, Howden-Ljungström Preheaters Ltd., is founded with exclusive manufacturing and sales for land use within the British Empire.
1925 Air Preheater Company (APC), USA, is founded - a joint venture between ALÅ & J. Howden, Societé de Fabrication d' Appareils Ljungström, France, is founded.
1927 New design without integral fans.
1928 Luftvorwärmer GmbH, Berlin Germany, is founded for sales in whole Europe.
1933 Totally 1,000 Ljungström Air Preheaters are delivered around the world.
1934 The first Ljungström International Technical Conference it London.
1937 ALÅ makes a profit for the first time in 15 years.
1949 Fredrik Ljungström is awarded the James Watt Medal from the Institution of Mechanical Engineers, London
1951 ALÅ changes name to Svenska Rotor MaskinerAB (SRM). The first idea for the multisector Ljungström Air Preheater was proposed by S Juhasz.
1956 Tests with a High Temperature Air Preheater.
1957 Fredrik Ljungstöm is awarded the first Ljungström Medal in gold from SRM.
1964 Fredrik Ljungström passes away. The first Trisector Ljungström Air Preheater.
1965 A total of 100,000 Ljungström Air Preheaters are delivered around the world.
1970 Commercialisation of the Trisector Ljungström Air Preheater
1976 The first Ljungström Gas Heater in service in Japan.
1990 A total of 20,000 Ljungström Air Preheaters are delivered around the world. The first installation of a commercial catalytic active Ljungström Air Preheater in Mandalay Power Station, California, USA for the denitrification of flue gases.
1994 The Ljungström Air Preheater is designated to be the 44th ASME International Historic Mechanical Engineering Landmark. Calamus AB purchases SRM.

The History and Heritage Program of the ASME

The History and Heritage Landmark Program of the American Society of Mechanical Engineers (ASME) began in 1971. To implement and achieve its goals ASME formed a History and Heritage Committee initially composed of mechanical engineers, historians of technology and the curator (emeritus) of mechanical engineering at the Smithsonian Institution. The Committee provides a public service by examining, noting recording and acknowledging mechanical engineering achievements of particular significance. The History and Heritage Committee is a part of ASME Council on Public Affairs and Board on Public Information. For further information please contact Public Information, American Society of Mechanical Engineers, 345 East 47 Street, NewYork, NY 10017-2392, 1 212-705-7740.

Designation

The Ljungström Air Preheater is the 44th International Historic Mechanical Engineering Landmark to be designated, the 11th to be designated outside of the United States of America.
Since the ASME Historic Mechanical Recognition Program began in 1971, 171 Historic Mechanical Engineering Landmark, 6 Mechanical Engineering Heritage Sites, and 6 Mechanical Engineering Heritage Collections have been recognised. Each reflects its influence on society, either in its immediate locale, nation-wide, or throughout the world. An ASME landmark represents a progressive step in the evolution of mechanical engineering. Site designation note an event or development of clear historic importance to mechanical engineers. Collections mark the contributions of a number of objects with special significance to the historical development of mechanical engineering.

The ASME Historic Mechanical Engineering Recognition Program illuminates our technological heritage and encourages the preservation of the physical remains of historically important works. It provides an annotated roster for engineers, students, educators, historians and travellers. It helps establish persistent reminders of where we have been and where we are going along the divergent paths of discovery.

The 125,000-member ASME is a world-wide engineering society focused on technical, educational and research issues. It conducts one of the world's larg est technical publishing operations, holds some 30 technical conferences and 200 professional development courses each year and sets many industrial and manufacturing standards

The American Society of Mechanical Engineers
Daniel T. Koenig, President
Walter W. von Nimitz, Vice President, International Affairs
Russell J. Grady, Nordic Correspondent
John R. Parker, Senior Vice President, Public Affairs
Erwin Fried, P.E., Vice President, Public Information
David L. Belden, P.E., Executive Director
David J. Soukup, Director International Affairs
Yesh P. Singh, P.E., San Antonio Section, Chair

The ASME History and Heritage Committee
J. Lawrence Lee, P.E., Chair
Robert M. Vogel, Secretary
William DeFotis
Burton Dicht
Robert B. Gaither
R. Michael Hunt, P.E.
William J. Warren, P.E.
Richard S. Hartenberg, P.E., Emeritus
Euan F.C. Somerscales, Emeritus
Diane Kaylor, Staff Liaison

Svenska Mekanisters Riksförening (SMR)
SMR is a Swedish society of engineers with a Master of Science Degree within Mechanical, Vehicle and Aeronautical Engineering. The aim of SMR is to promote the technical and industrial development as well as a good spirit among its fellows.

Address
Kommendörsgatan 16
P.O.Box 5164, 102 44 STOCKHOLM, SWEDEN
Phone: +46 8 667 93 20
Telefax: +46 8 667 97 05

Officials
Jan-Gunnar Persson, President
Lars-Torsten Olsson, Vice President
Mats Lindgren, Treasurer
Olle Rutgerssson, Secretary

Acknowledgements

The American Society of Mechanical Engineers is grateful to all those who have contributed to the designation of the Ljungström Air Preheater as an International Historic Mechanical Engineering Landmark. Special thanks to Dr Stephen Juhasz who was the initiator and prepared the nomination material, to Eugene Krumm ABB Air Preheater Inc for being the copreparer of the nomination material, to Dr Stefan Essle, SRM for writing the commemorative brochure, and to the Ljungström Landmark Committee: Gert Ekström, Tekniska Museet, Dr Olle Ljungström, Prof Em Carl-Göran Nilson, Prof Jan-Gunnar Persson, KTH & SMR and Bo Sångfors, SRM for supplying materials and co-ordinating the ceremony.

The American Society of Mechanical Engineers also wants to thank the sponsors who financially have supported the ceremony and the permanent exhibition at Tekniska Museet, Stockholm:

ABB Air Preheater Inc, Wellsville, USA
ABB Gadelius KK, Kobe, Japan
ABB STAL AB, Finspång, Sweden
Asea Brown Boveri AB, Västerås, Sweden
James Howden Ltd, Glasgow, Scotland
Kraftanlagen AG, Heidelberg, Germany
Svenska Rotor Maskiner AB, Nacka, Sweden
Tekniska Museet, Stockholm, Sweden

Internationellt Historiskt Minnesmärke för Mekanisk Ingenjörskonst
Ljungströms Luftförvärmare
Stockholm 1920

DR. FREDRIK LJUNGSTRÖM UPPFANN DEN ROTERANDE REGENERATIVA LUFTFÖRVÄRMAREN FÖR ATT ÖKA VERKNINGSGRADEN I ÅNGPANNOR. DEN ANVÄNDEVÄRMELAGRANDE, LÅNGSAMT ROTERANDE, TÄTT PACKADE KORRUGERADE PLÅTAR AV STÅL FÖR ATT INDIREKT ÖVERFÖRA VÄRMET FRÅN DE VARMA AVGASERNA TILL DEN INKOMMANDE FÖRBRÄNNINGS-LUFTEN.LJUNGSTRÖMS LUFTFÖRVÄRMARE VISADE SIG VARA ENKEL, EFFEKTIV OCH TILLFÖRLITLIG. MER ÄN 20.000 HA INSTALLERATS ÖVER HELA VÄRLDEN, DE FLESTA I ÅNGKRAFTVERK OCH ÅSTADKOMMER VÄSENTLIGA BRÄNSLE-BESPARINGAR. TEKNIKEN TILLÄMPAS IDAG ÄVEN I ANLÄGGNINGAR FÖR RENING AV RÖKGASER.

SMR
SVENSKA MEKANISTERS RIKSFÖRENING
1995

International Historic Mechanical Engineering Landmark
Ljungstoröm Air Preheater
Stockholm 1920

DR. FREDRIK LJUNGSTRÖM INVENTED THE REGENRATIVE AIR PREHEATER TO IMPROVE THE EFICIENCY OF STEAM BOILERS IT IS USED HEAT STORING SLOWLY ROTATING CLOSELY PACKED, CORUGAATED STEEL SHEETS TO TRANSFER HEAT INDIRECTLY FROM THE HOT FLUE GASES TO THE INCOMING COMBUSTION AIR THE LUNGSTRÖM AIR PREHEATER PROVED SIMPLE EFFECTIVE AND RELIABLE. MORE THAN 20,000 HAVE BEEN INSTALLED WORLD-WIDE, PRIMARILY IN STEAM-ELECTRIC POWER PLANTS TO PROVIDE SIGNIFICANT FUEL SAVINGS. APPLICATIONS TODAY ALSO INCLUDED ENVIRONMENTAL CONTROL

THE AMERICAN CITY OF MECHANICAL ENGINEERS
1995

H185