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SVENSKA ROTOR MASKINER AB

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The

Screw Compressor Development

at SRM

100 YEARS OF ENERGY EFFICIENCY

The Screw Compressor Development at SRM

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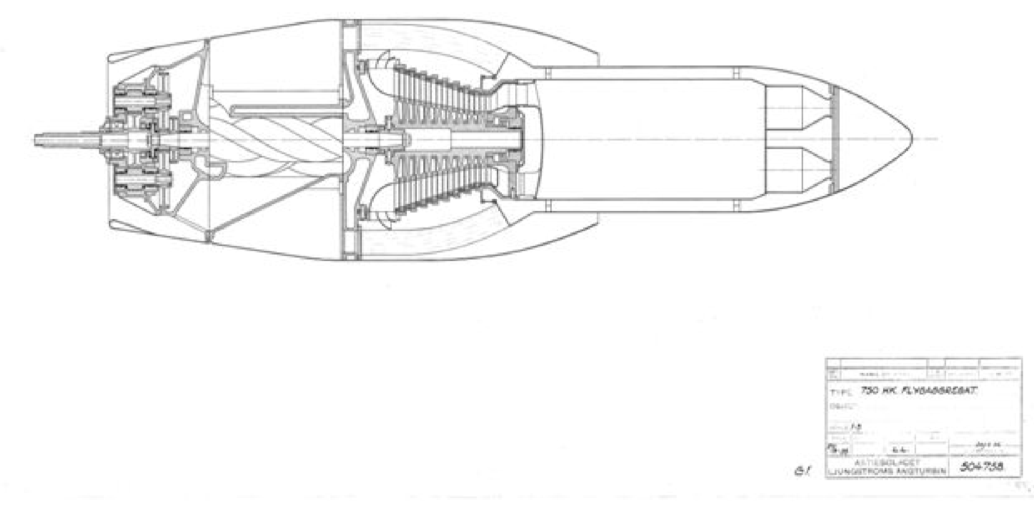
In the early 30´s Svenska Rotor Maskiner AB (SRM), at that time named The Ljungström Steam Turbine Co., was engaged in experiments with gas-turbine units. In view of the difficulties with surging, experienced with the centrifugal and axial-flow type compressors at that time, our company started the development of a new type of compressor, intended to meet the requirement of a high average efficiency under most varied conditions of pressure and speed, a high maximum efficiency - preferably above 85 % - with small bulk, low weight and also suitable for direct drive from a turbine.

A penetrating study of the problems to be solved led to the development of the positive-displacement rotary compressor, having two cooperating rotors with helical lobes and grooves, running dry with small clearances between the rotating parts and the housing and achieving a pressure ratio of more than 2:1 in one stage. The first application was aircraft turbo-prop engines, later reaction engines as shown.



During the years 1935-1945 we designed and tested some 70 screw compressors with rotor diameters from 50 to 530 mm and rotor lobe combinations 3+3, 3+4, 4+4, 4+6 and 5+7.

The basic theory and design parameters for dry-running screw compressors were worked out. To satisfy the theoretical criteria for obtaining high efficiency, the female-rotor grooves were given asymmetric shape with the leading flank circular and the trailing flank generated by the tip of the male rotor. In spite of World War II, which restricted our possibilities, a few licences were granted for this compressor type, named the Lysholm Compressor after its originator Mr. A. Lysholm, Chief Engineer of our company. Though some pilot installations worked out very well, it proved difficult in practice to achieve sufficient manufacturing accuracy to ensure trouble-free operation of the compressor.

After World War II we started work to develop a rotor profile with less risk of damaging the sealing edges due to thermal distortion or errors in timing of the rotors and in 1946 we decided to introduce the circular symmetric profile.

In the years 1947-1950 about 25 test compressors with rotor diameters 110 to 400 mm with lobe combinations 3+4, 3+5, 4+4, 5+7 and 4+6 were designed and the characteristics and performance of dry compressors with symmetric circular profiles were determined.

Based on the evaluation of the test results, SRM issued early in 1951 report 839/K-74 "Calculation of the Characteristics of the Screw Compressor" and report 841/K-75 "Standardization of Screw Compressors" closely followed by report 847/K-80 "Regarding Available Tooling Machines (American and European) for Manufacture of Rotors for Screw Compressors".

It was shown that, provided a maximum variation of four percent from top efficiency can be accepted over the speed range of a compressor, the capacity range 1 to 310 m^3/min can be covered by six standard rotor diameters (63, 100, 160, 250, 400 and 630 mm) with lobe combination 4+6 and for each rotor diameter a length to diameter ratio of 1.0 and 1.5, using only six sets of rotor cutting tools. Complementary standard sizes were proposed in 1952 in SRM report 877/K-94.

In order to promote the manufacture of screw compressors among our licensees (nine companies in 1952), SRM undertook to keep rotor cutting tools for some standard sizes (dias 125, 160, 200 and 250 mm) available at J. Holroyd & Co., who undertook to develop and supply rotor-milling machines for SRM´s licensees.

At the Technical Compressor Conference at SRM in October 1953, when delegates from eleven companies participated, experiences were exchanged and it was also commonly accepted that the 4+6 lobe combination and standard symmetric profile with equal bore as proposed by SRM, did give a compressor that was usable for a wide range of pressure ratios and tip speeds. However, in cases when efficiency, weight, bulk or competition from others makes it necessary, other lobe combinations (e.g. 3+4, 6+8) and modified profiles might be suitable.

A late but striking proof that the screw compressor was ready for the market in the early 50´s is that some dry screw compressors (dia 500 mm) designed already in 1950 and delivered in 1952 to the Municipal Gas Works of Stockholm were in operation for some 30 years, with only two short stops for replacing synchronizing gears and sleeve bearings until the production of gas from coal ceased in the early 80´s.

During the years 1953-1958 some 600 dry screw compressors for stationary use, with symmetric profile and dias 65 to 630 mm, were produced by SRM licensees.

During the late 1950’s more complex solutions as “herring bone” and 3-rotor-compressors were developed. However, commerciality they were not able to outperform conventional 2-rotor compressors.

Lightweight designs for airborne applications were introduced in 1956, and already during the period 1956-1958, 425 units were produced. By 2007 roughly 3000 airborne screw compressors per annum were sold and the volumes keep increasing. (Helicopters, cruise missiles, Airbus, Gulfstream etc.)

In parallel with the "dry" compressor entering the market, R & D-work was carried on as to methods and means for injecting a fluid (oil) into the compression chamber for cooling, sealing and lubrication purposes. By injecting suitable oil qualities and quantities, the synchronizing gears and shaft seals could be omitted, the tip speed could be reduced, step-up gearing became unnecessary, and antifriction bearings could be used. Oil-separation systems, as used for rotary-vane compressors, could be adopted. As this type of screw compressor proved to be less sensitive to impure air, and most likely would require less maintenance, it had good sales features. This development started in 1955 and already in 1958, the oil-injected screw compressor entered a new field of application: portable compressors for compressed air. Several well-known compressor manufacturers took interest in this new development and acquired SRM-licences in the early 60´s. By the end of 1965, more than 10 000 oil-flooded air compressors had been produced.

Having successfully introduced the oil-flooded air compressor, SRM launched a further R & D-program for investigating the idea of adopting oil-flooded screw compressors for refrigerating purposes, whereby in view of the requirements in this new field of application, a slide-valve arrangement for stepless capacity-control was integrated in the compressor.

Several firms working in the refrigeration field became interested and acquired licences. The first deliveries were made in 1964 and within 5 years, more than 1 000 refrigeration screw compressors were produced. In 2006 roughly 80% of the world wide production of screw compressors is manufactured by SRM’s licensees.

In the latter part of the 60´s, theoretical analysis and R & D-efforts were made to improve the efficiency of the screw compressor, aiming at penetrating the market for stationary air-compressors as well as increasing the competitive power in general.

This work resulted in what has become known as the SRM-asymmetrical profile (not having the drawbacks of the Lysholm asymmetrical profile, which we abandoned in the late 40´s) and giving 10 to 15 % less specific power consumption than screw compressors with the symmetric circular profile.

The SRM asymmetric profile was gradually adopted during the 70´s, and with increasing market penetration and increasing numbers of especially smaller screw compressors (dias 63 to 127 mm) new manufacturing methods (hobbing) became of particular interest. This resulted in a modification of the profile form, leading to easier manufacture of the rotors.

Though the SRM asymmetric profile represented a considerable progress, no pain was spared to achieve further improvements. In 1982 we began the release of what we call the D-profile, which in fact is not a specific profile, but a versatile system for determining the best profile for any single application, taking into account performance-related data, aspects of reliability and life, economy-related factors such as rotor materials and manufacturing methods. The computerized calculation system provided a comprehensive soft-ware package for evaluation of the D-profile recommended for the application.

The D-profile concept has proven its abilities in countless applications from very small oil injected compressor to the largest oil free screw compressor ever built, with a rotor diameter of 845 mm. All-in-all, more than 400 different D-profiles have been developed.

During the 1990’s and 2000’s new, more powerful and accurate, manufacturing technologies emerged as well as new screw compressor applications. Some limitations in the D-profile requested further development resulting in a wide flora of profiles such as the G- and H-profile systems.

The G-profile concept, which is a further development of the D-profile, has currently proved its values in high rotor contact load applications. (Examples are very low viscosity lubrication, operation with lower quality production rotors and 70 bar pressure differential operation.)

The R & D-work at SRM has not only been concentrated on the rotor profiles, but includes several other items of importance for screw compressor technology, for example:

Development work at SRM of the movable slide-stop concept resulted in the variable volume-ratio for refrigeration compressors successfully introduced in the early 80´s.

Novelty bearings, seal and drive technologies as well as system integration technologies such as economizer, super economizer, enthalpy control and side loading etc. etc. have been invented, built, tested and displayed to our licensees.

With the development of heavy duty compressors for 70 bar single stage compressors during the 1990’s and the oil free, water lubricated air compressors during the 2000’s entirely new technologies have been shown to be commercially successful in fierce competition with older products.

SRM has always been actively involved in developing and evaluating new manufacturing processes and materials for screw compressor rotors. During the last twenty years SRM has been engaged in the development, testing and evaluation of processes such as: casting, whirling, hobbing, grinding, extruding, isostatic powder-metal forming, injection moulding of plastic rotors etc. Also new milling cutters have been tested and further developed, e.g. titaniumnitrided single-index cutter blades and hobs, zig-zag-cutters for finish milling and profile grinding methods for soft grinding wheels.

Many other lines of screw compressor development are being pursued, leading to continuous test-work and evaluation in the SRM laboratories.

The design and features of the screw compressor are based on a number of inventions, which have successively been protected by patents. Since the start in the 30´s, more than 120 inventions related to screw compressors have resulted in over 800 SRM Letters Patents.

Several of SRM’s current patents are valid beyond 2020 and new innovations are produced continuously.

So far SRM licensees have delivered in all more than three million screw compressors for various purposes, the main fields of applications being compressed air (85 %) and refrigeration and air-conditioning (12 %). Future applications of mass produced smaller sizes of oil-injected screw compressors for air-conditioning, adapted to the new types of refrigerants, and of dry screw compressors for supercharging combustion engines as well as mobile fuel cells will no doubt considerably modify these figures.

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SRM Screw Compressor Licensees 2008

Company	*Country*	*Licence granted in*
Howden Compressors	GB	1946
SJA	SE	1947
Avesta Jernverks AB	SE	1949
Aerzener Maschinenfabrik	DE	1950
Alsthom Atlantique (earlier SACM)	FR	1950
SAAB	SE	1952
Atlas Copco	SE	1954
Kobe Steel (Kobelco)	JP	1955
Howden Airdynamics (earlier Godfrey)	GB	1955
Stratos/Fairchild	US	1956
Quincy Compressor (earlier Fairbanks Morse)	US	1956
GHH (MAN-TURBO)	GE	1957
GM (General Motors)	US	1957
Ingersoll-Rand	US	1958
Joy Manufacturing Company	US	1960
STAL Refrigeration	SE	1962
Tammerfors Linne- och Jernmanufactur AB, Tamrock, Tamrotor, Gardner Denver Oy	FI	1963
Gardner Denver Co	US	1963
Hartford Compressors (earlier Dunham-Bush)	US	1965
CKD	CZ	1965
Sullair	US	1965
Hitachi Ltd.	JP	1965
Mayekawa Mfg. (Mycom)	JP	1966
Mitsubishi Heavy Ind. (MHI)	JP	1969
Le Roi International	US	1969
Linde AG	GE	1971
Ishikawajima-Harima Heavy Ind. (IHI)	JP	1972
Kühlautomat (Grasso)	DE	1972
Worthington-Creyssensac	FR	1973
A-C Compr. Corporation (General Electric)	US	1973
Demag	GE	1974
Sabroe	DK	1975
Sabroe Refrigeration	DK	1975
Hughes Aircraft Company	US	1978
Frick/York (JCI)	US	1980
Trane Co.	US	1980
CompAir	UK	1985
Century Corp.	KR	1986
Thermo King Corporation	US	1987
Grasso Products	NL	1987

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Carrier	US	1987
Gram Refrigeration (earlier Brød. Gram)	DK	1988
Termomeccanica SpA	IT	1989
Vilter Manufacturing Co.	US	1989
Ebara Corporation	JP	1991
Opcon Autorotor	SE	1991
Liebherr Aerospace	FR	1993
Lysholm Technologies	SE	1995
Cooper Cameron	US	1998
Eaton Corp.	US	1998
Kirloskar Pneumatics	IN	2001
Nanjing Compressor	CN	2001
Kyungwon Machinery Co. Ltd.	KR	2004
AirPower Group	US	2009