History of Mechanical Vacuum Pumps in the United States

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ABSTRACT

Mechanical, oil-sealed, vacuum pumps have been the backbone for all vacuum endeavors. Whether it is roughing a system from atmosphere or supporting a high vacuum/ultra-high vacuum pump, they have been indispensable. Some designs that appeared on the market have been revolutionary, while others are evolutionary. This presentation will deal only with those oil-sealed pumps originally developed and produced within the United States, though they may have been distributed and licensed throughout the world.

The presentation provides an historical and detailed review on the development of these pumps and their effect on the vacuum industry from the early 1900s to the mid 1970s. The account covers many different areas of vacuum application, as well as interaction of these vacuum pumps. In the chronicles of pump production, some organizations have been industry leaders only to lose position, due to advancements from competitors. And other leading manufacturers fell from favor to the point of complete company dissolution.

Different pumping mechanisms also will be discussed, with an evaluation of their efficiency and current place in the scheme of mechanical pumping. This will include not only ultimate working pressures but also effective pumping speeds. Plus, various features that have been added to these pumps will be reviewed in chronological order.

INTRODUCTION

The full title of this paper should include the words "of the Rotary, Oil Sealed type, Manufactured in the USA, Through the Year 1971". And to further define this paper, the pumps involved needed to attain a pressure of 1 Torr or lower. For various mechanical pumps had been in use in scientific applications in the U.S. throughout the nineteenth century. And by the 1880's and 1890's, they were also in industrial applications, such as the lamp industry which made use of mechanical pumps. Types such as Fleuss patent Geryk-Oil-Air piston pumps, Sprengel [1] and Toepler mercury droplet pumps, even the rotary mercury pumps of Gaede [2] and others (in early 20th century). But it wasn't until 1917 that rotary, oil sealed mechanical pumps, that were manufactured in the U.S., came into use. In chronological order, we will report on these latter manufacturers (see alpha list in Table 1).

DETAILS

1917 – Central Scientific Co., founded in Chicago in 1889, began the manufacture and sale of a multistage, oil sealed, gear pump, for laboratories and schools. Using two counter rotating gears in each stage pocket, gas was transferred around the periphery of the gears, from inlet to outlet. Multi-staging eliminated the need for higher compression ratio exhaust valves. Pumping speed was low, 2-3 liters per minute, and ultimate limited to 500 millitorr, but since this was electric motor driven, it was a major improvement over the hand actuated devices.

1921 – Central Scientific Co., in 1921 [3], initiated manufacture of what became the world famous Cenco Hyvac, two stage, vacuum pump. This belt driven, oil sealed pump, used an eccentric cast iron cam (rotor) on the pump shaft, with the shaft mounted concentrically in the stator or cylinder (see Figure 1). A very small clearance between the outer diameter of the cam and the inner diameter of the stator, was sealed by the ever replenished oil film. A steel blade or vane, was mounted tangential to the rotor, in a slot of the cast iron stator. A spring loaded arm, kept the vane in constant contact with the rotor, but a film of oil prevented metal to metal contact. Steel balls in spherical seats, served as exhaust valves. Gas was transferred from stage to stage through internal porting. While the pumping speed was only 10 liters per minute (0.35 CFM), the ultimate pressure was an amazing 3×10^{-4} Torr. Later, the rotational speed of the pump was doubled, to provide a 20 l/m pumping speed, without loss of base pressure. Central Scientific quickly added the Megavac model, with 57 l/m, and since it was also 2 stage, the same base pressure as the Hyvac, for use in the ever-growing lamp industry. Other models, upward of 34 CFM, were added over the years.

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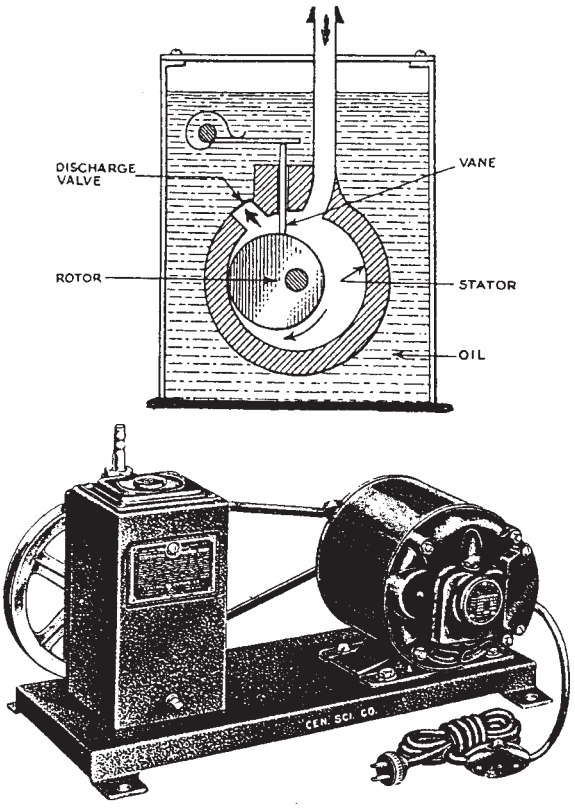

Figure 1: Eccentric Cam/External Vane design, Central Scientific Company

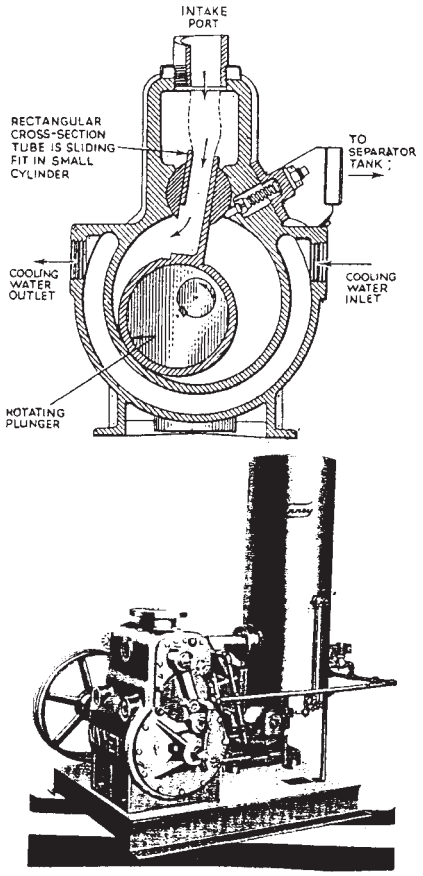

Figure 2: Rotary Piston design, Kinney Manufacturing Company

1926 – Kinney Manufacturing Co. Royal Kinney is credited, in 1909 [4], with developing the rotary piston pump. In 1926, their vacuum pump was the popular model VSD-8811 (later changed to the KS-47), oil sealed, rotary piston pump, of single stage design (see Figure 2). In this design, a cam is mounted onto the pump drive shaft. The hardened cam fits within a hollow cast iron part, called the piston, that has an extension tangential to the piston diameter. This extension is generally called the piston vane. The pump shaft is mounted concentrically in the pump housing and end plate. The piston vane extension fits into a cylindrical part, the hinge bar that can rotate back and forth, on its diameter. The hinge bar assembly prevented the piston from rotating, so that as the cam is revolved by the drive shaft, the piston oscillates within the pump housing. This flat belt driven pump had a free air capacity of almost 40 CFM, and an ultimate vacuum of 20 millitorr. Other models and sizes were added to the product line, so that by World War II, they were producing pumps ranging from 13 to 700 CFM in pumping speeds, and ultimate vacuums of 1 x 10^{-4} Torr.

1927 – Nelson Vacuum Pump Co., which traced its origins to 1910, developed a single stage vacuum pump, for the scientific and industrial laboratories. The oil sealed pump, patented in 1928, utilized an oval, cast iron rotor/ steel shaft assembly, mounted in a large bronze bushing, within a concentric housing (see Figure 3). Two external, spring loaded, bronze swing vanes, followed the action of the rotor, with the pump oil closing up all clearance gaps, as well as preventing metal to metal contact. The first or left hand vane, sealed the vacuum producing area from the atmosphere. The second vane served as the exhaust port, for the gas raised above atmospheric pressure. A flat steel plate sealed these parts from the oil reservoir. Through the leather belt drive, the pump shaft was driven by an electric motor. The first pumps had a capacity of 15 liters per minute and an ultimate of 2 x 10^{-2} Torr. Later versions provided 24 l/m (0.85 CFM) and 10 millitorr. Additional models resulted in capacities up to 8.0 CFM. Some early versions were modified to provide vacuum-pressure applications, for teaching high school physics. This was probably the simplest design vacuum pump ever produced.

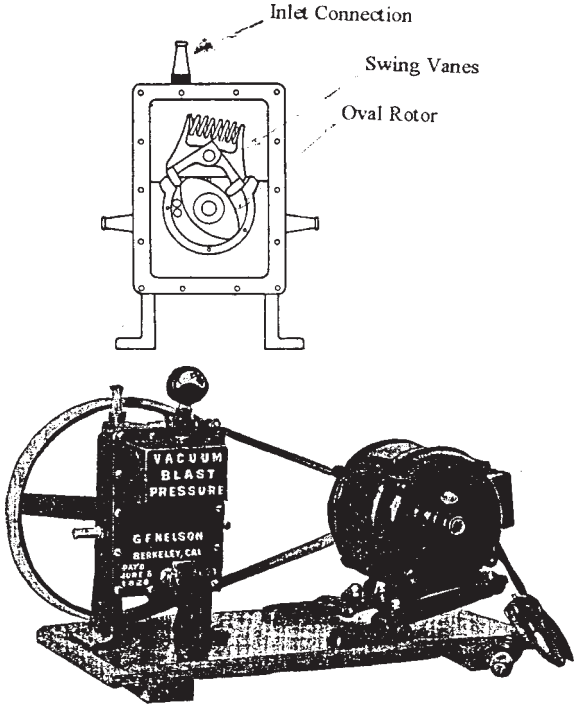

Figure 3: Oval Rotor/External Swing Vanes design, Nelson Vacuum Pump Company

1934 – W.M. Welch Scientific had been a laboratory furniture manufacturer since 1880. It was a distributor for laboratory apparatus and other manufacturer vacuum pumps, until they introduced the belt driven Wegner Micro-Deka, in 1934. This oil sealed, rotary vane, mechanical pump, provided 17 liters per minute pumping speed, and 25 millitorr ultimate (see Figure 4). It used the 1907 Gaede [5] style design of a rotor, mounted on a drive shaft that was itself mounted eccentrically in the cylinder or stator. At the point of almost contact, between the rotor and the stator, a radius (equal to the rotor dimension) was cut into the stator. This radius, where the rotor and stator almost contact, is called the Arcuate Seat or Arcuate Seal. Within slots of the rotor were positioned two, spring loaded, sliding vanes. As the rotor was turned, the vanes would move out of the rotor, trying to rub against the inside diameter of the stator, then after bottom dead center point, start moving back into the rotor. A simple finger valve, kept atmospheric gas away from the compression part of the evacuation cycle. Other larger and two stage models followed, so that by 1950, Welch had eight models in the product line, for both laboratory, as well as industrial applications. In 1966, the product line topped out at 9 distinct models in the v-belt drive catalog.

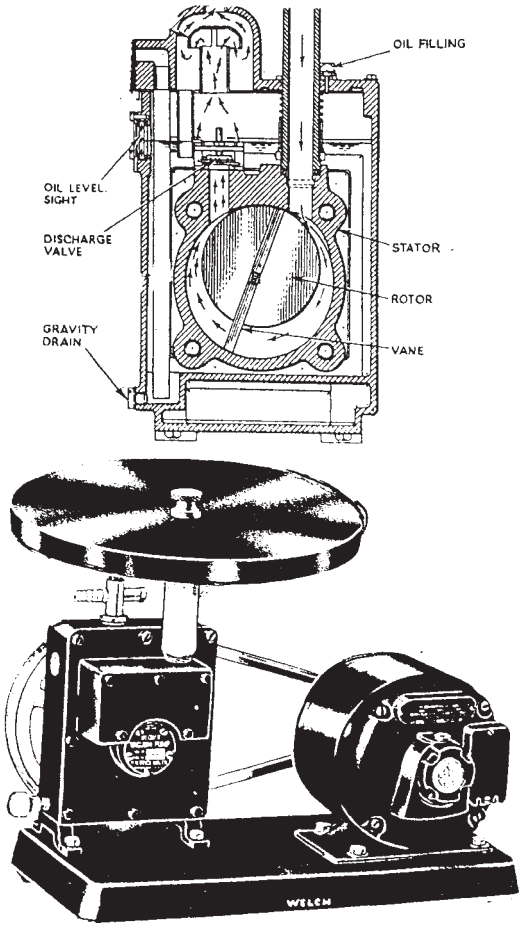

Figure 4: Rotary Vane design, W.M. Welch Scientific Company

1936 – F.J. Stokes Machine Co. had been involved, since 1895, with building various machines, that utilized low pressure for their operation, and in 1936, introduced their version of the belt drive, oil sealed, rotary piston, vacuum pump. Their design concept used an articulated vane extension, as their improvement on the existing design. And, as opposed to Kinney Manufacturing, they produced only Simplex and Duplex pumps (if there was more than one stage, the stages had common inlet/outlet), never compound pumps. They mounted the drive motor on top of the pump housing, to save floor space. And for balancing purposes, they introduced the use of two flywheels, one on each end of the shaft, to counterbalance the eccentric. Their product line ranges from 17 CFM to over 500 CFM models, with the larger water cooled.

1941 – Beach-Russ Co. had been building compressors, rough and medium vacuum pumps for several years, since their beginning in 1898. They introduced their RP series of Gaede style, oil sealed, rotary vane (see Figure 5), vacuum pumps, in 1941 [6]. Essentially large, industrial pumps, they proved invaluable in the Manhattan Project of World War II. They were also used for altitude simulation, drying systems, food plants, heat treating and similar rugged applications in heavy industry. Pump sizes range from 8.5 to 1100 CFM, mostly in single stage, belt drive, configuration. Compound models use the concept of two separate pumps, driven by a common motor. Later vacuum pump models included smaller, portable, direct drive versions, for servicing refrigeration/air conditioning systems.

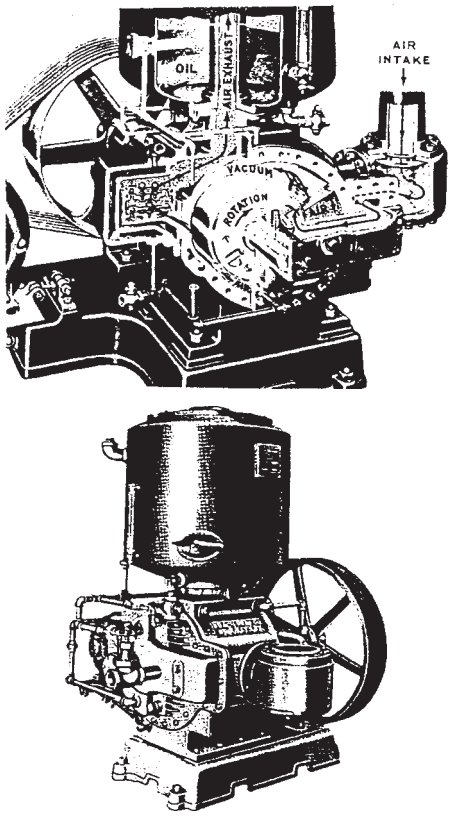

Figure 5: Rotary Vane design, Beach-Russ Company

1955 – Red Point Corp. had been building coating and impregnation equipment for the war time industries. When they built vacuum impregnation equipment, at first they used other manufacturers' pumps. But, in 1955 they built their own, belt driven, oil sealed, rotary vane pump, the model 22BF. This 0.62 CFM pumping speed, 1 Torr ultimate unit, didn't use an Arcuate seal of Gaede's design, thus limiting the ultimate pressure of the pump. But for impregnation, coating, packaging applications, the pressure was sufficient.

1957 – Precision Scientific Co. began in 1920, as a producer of laboratory baths, ovens and refrigerators. In 1957, they developed a line of belt driven, oil sealed, high vacuum pumps. Using the Gaede style, rotary vane design, they introduced a laboratory size 25 l/m (0.88 CFM) model. This 1 x 10^{-4} ultimate pump was quickly followed by 3 and 5.25 CFM laboratory models, and then up to 53 CFM pumps, for industrial applications. Internally, they had an innovative approach of rotating the second stage inlet, some 25 degrees from the first stage exhaust, so it was a direct passage from one stage to the other [7]. Being a later introduction into the vacuum pump field, their overall external appearance had a more pleasing design concept. Lower sound level and reliability, were also some of their features.

1957 – Langmar Corp. produced the Langdon 35, direct drive vacuum pump, for a specific application, organic distillations in the laboratory (see Figure 6). This 35 l/m, 50 millitorr pump was an instant success, due to its smaller size and lower price than equivalent capacity models. Teflon™ vanes, non-spring loaded, worked very well at 4-pole motor speed, and eliminated a wear problem. The pump was designed for rapid oil changing and easy servicing, and created great interest in direct drive vacuum pumps, probably being a driving force to the smaller, lighter, lower cost concept of such vacuum pumps. A large non-vacuum organization purchased this successful company.

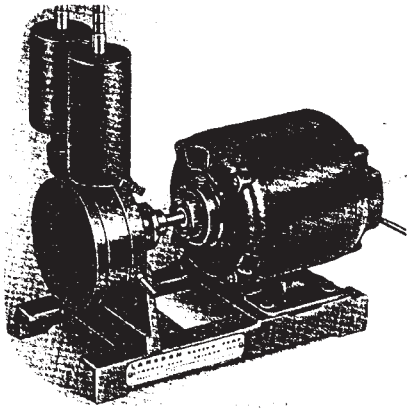

Figure 6: Langdon Rotary Vane—direct drive

1958 – Arthur F. Smith Co. an organization involved in molecular thin film chambers, built their own vacuum pump, initially for their own equipment. In a revolutionary vertical mounting of the Gaede style vane pump, they provided a pump they wouldn't leak at the oil case flange or shaft seal, onto the floor. And a reduced floor footprint was a distinct advantage, for the 1.85 CFM pump, that operated at 1140 RPM (see Figure 7).

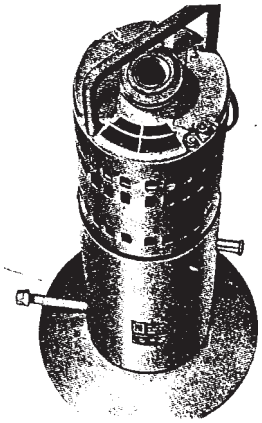

Figure 7: ASCO Rotary Vane—vertical

1959 – Morris and Lee Co. was an exception to the rule of building their own vacuum pump, for they modified the Norge Rollator [8], belt driven (and mass produced-lower cost) refrigeration compressor (see Figure 8). The Rollator was similar in design to the Cenco Hyvac, with an eccentric cam and external spring loaded vane. By installing inlet and outlet fittings, and putting the compressor on a small base with a motor and cord set, they had a vacuum pump, with almost 0.8 CFM capacity and 150 millitorr base pressure. And it was low priced!

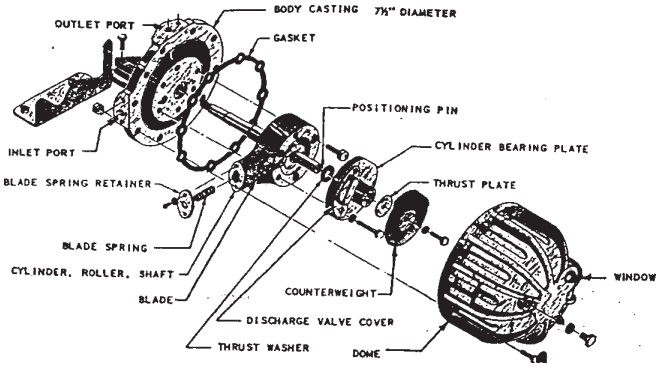

Figure 8: Norge Rollator™ Cam/Ext. Vane, modified by Morris and Lee Company

1959 – Marvac Scientific Co. began by building the more traditional, belt driven, rotary vane vacuum pump. Ranging from 0.85 CFM to 15 CFM, in one and two stage versions, these pumps were used in various laboratory applications.

1971 – Robinair Manufacturing Co. had started out as a supplier of service tools in the air conditioning/refrigeration market. But since evacuation is an integral part of servicing such a system, they first distributed other makes, and then built their own vacuum pumps. Their first models were oil sealed, rotary piston pumps, belt driven. Built in the smaller sizes required by that market, they ranged from 1.2 to 5.0 CFM. Within a year, direct drive models, smaller and very much lighter, replaced many of the original, but equivalent capacity pumps. Shortly after, they also produced a successful 1 CFM model.

1971 – Lammert Industries was an outgrowth of a rough vacuum, drip lubricated, rotary vane pump manufacturer. Like Robinair, they also developed their new, oil sealed, pump for the air conditioning/refrigeration service market. But their first pump started out as a direct drive, Gaede style, rotary vane pump. Pumping speed, low weight and vacuum in the 20 to 30 millitorr range, were the major criteria.

THE EBB AND FLOW OF ROTARY, OIL SEALED, VACUUM PUMP MANUFACTURERS

The 1920's and 1930's - While the Central Scientific rotary, oil sealed, multi-staged, gear vacuum pump of 1917, may have been the first commercial unit, the limitations in pumping speed and ultimate pressure, meant limited applications. Though the Gaede style vane pump was being produced in Europe, the first commercial, but successful oil sealed pump in the United States, was the Cenco Hyvac of 1921. Even though by today's standards, the pumping speed was very small, it was quite adequate for laboratory use and backing of 25 to 37 mm OD diffusion pumps. The larger Cenco Megavac model, with the same eccentric cam/external vane design, expanded the laboratory use and opened up a wide area of industrial uses in the lamp and tube industries. The Kinney rotary piston pump of 1926 amplified the industrial applications for rotary, oil sealed, mechanical pumps, leading into applications such as product distillation, metal refining, food drying and many others. The single stage pump of the Nelson oval rotor/external vanes design, had a limitation in ultimate vacuum and capacity, so it remained a scientific/industrial laboratory pump. The entry of the Welch rotary vane pump in laboratory use and the Stokes rotary piston pump in industrial applications, were in the last quarter of the two decades. So, during this period, the two major brands were the Central Scientific line of Cenco pumps for the laboratory and some industry, and the Kinney products for industrial applications.

The 1940's - This decade saw the entry of Beach-Russ, with their version of the rotary vane pump, into industrial application. And, in general, the beginning of World War II in Europe in 1939, then the United States entry into the conflict in late 1941, saw a tremendous need for rotary, oil sealed, mechanical pumps. This was true, not only in the basic industries developed in the prior two decades, but in the new atomic energy program. These vacuum pumps were a top priority war material, and demand initially outstripped production. However, by the end of the war, vacuum pump supply was steady. All of the manufacturers had increased their manufacturing

capabilities and, with just one exception, their product line of vacuum pumps. The economic demand lasted almost through the decade. Central Scientific and Kinney were still the individual leaders in number of units sold, in their respective markets.

The 1950's - In this decade, there was a growth of vacuum applications, far beyond that of a growth of the general economy. Vacuum melting of metals, thin film coatings, freeze dried foods, space study after Sputnik, all demanded more in the way of oil sealed, rotary, mechanical vacuum pumps. The line between laboratory vacuum pumps and industrial pumps blurred, as the traditional laboratory vacuum pump suppliers, Central Scientific and Welch Scientific, increased the pumping speeds of their products. And, as the need for larger pumps arose, Central Scientific's sales lead, over their primary rival Welch, diminished. As a means of boosting their market share, the Cenco Hyvac 2/7/14/28/etc. were introduced. These new Cenco pumps embraced the Gaede style rotary vane design, versus the original Hyvac eccentric cam/external vane. And, new players were entering the vacuum pump manufacturing field. Red Point in small industrial application vane pumps, sought some of both Central Scientific and Welch Scientific sales, And the laboratory pump sales of the two latter companies were also slightly impacted by Langmar Corp., Arthur F. Smith Co., Morris and Lee, and Marvac Scientific. Much more important to Cenco and Welch however, was the impact of an existing laboratory apparatus supplier, Precision Scientific, who entered the market with a line of equal performance, but superior appearance pumps. The first successful direct pumps were in the late 1950's. By the end of the decade, Welch was #1 in laboratory size pump sales, Central Scientific a close second, Precision a distant third. In rotary piston pump sales, Kinney's lead (they became part of New York Air Brake) over Stokes was shrinking.

The 1960's - This decade has been called the Golden Age of Rotary, Oil Sealed, Mechanical Pumps. The overall market for these types of vacuum pumps continued to rise. And a new ever increasing factor, was the increase in residential air conditioning, and commercial refrigeration. To service these devices, evacuation with small mechanical pumps was essential, before the refrigerant was recharged. Kinney and Beach-Russ had been the leaders in this market in the 1950's, but this decade's boom was handled by all of the small pump manufacturers, some selling by private branding, others through distributors. Adding in all the growth of the space industry, resulted in increasing sales volumes for most manufacturers. Many pump manufacturers were looking at direct drive models in their R&D, but large pump sales for all, took away much of the motivation for change. During this decade, Welch (who merged with E.H. Sargent Supply into Sargent-Welch Scientific) increased their sales volume lead over all their competitors. And Stokes (with their increased sales volume in the heat treat industry) overtakes Kinney. However, imports from Edwards, Leybold and Alcatel, were on the rise.

The 1970's - The was the Last Great Decade of rotary, oil sealed, mechanical vacuum pumps. Overall sales volume increased, with the multitude of uses for these devices. But the astronomical growth in the refrigeration/air conditioning service market, made this the largest sales field in simple units. The entrance of Robinair and Lammert, along with a host of private brand, in almost the beginning of the decade, heralded this rise. But there was also a new market in the growth pattern, the semiconductor industry. Here, the aggressive particulate and corrosives, generated in the LPCVD chambers, coined the words "disposable pumps", due to very short working lives. In this growing area, import rotary, oil sealed pumps were starting to dominate. However, the overall growth of these pumps, was also creating consolidation in the industry, with Central Scientific sold to Boekel Industries of Philadelphia, Lammert to Sargent-Welch and Nelson to Ace Pump of Memphis. And there was the demise of Arthur F. Smith, Langmar, and Red Point in this same period. The end of this decade saw Sargent-Welch fall to second place in overall sales.

Table 1: Alphabetical Listing—USA Pump Manufacturers, 1900–1971

Name at Start	Trade Name	Pump Types	First Mfg'd	Original Location	Details and Present Name/Address
Arthur F. Smith Co.*	ASCO	Rotary Vane Direct	1958	Rochester	Moved to Pompano Beach, FL. Then sold to All Starr Scientific, now out of business
Beach Russ Co.		Rotary Vane Belt & Direct	1941	New York	Beach Russ Co. 544 Union Ave., Brooklyn, NY 11211
Central Scientific Co.*	Cenco	Eccen Cam/ Ext. Vane Belt Drive Rotary Vane Belt & Direct	1921 1955	Chicago	Sold to Boekel Indus in late 70s, then to HyVac Products in 1990, now: HyVac Products Inc. 201 North 5th Ave., Royersford, PA 19468
Kinney Mfg Co.		Rotary Piston Belt & Direct Rotary Vane Belt	1926 1961	Boston	Originally bought by New York Air Brake then in 1996 sold to Tuthill Corp., now: Tuthill Vacuum Systems 4840 W Kearney, Springfield MO 65801
Lammert Industries*		Rotary Vane Direct	1971	Addison, IL	Bought by Welch and integrated into their product line, no longer available
Langmar Corp.*	Langdon	Rotary Vane Direct	1957	Chicago	Bought by HeviDuty div of Basic Indus in Watertown, WI; discontinued early 70s
Marvac Scientific		Rotary Vane Belt & Direct	1959	Berkeley	Marvac Scientific Mfg Co. 3231 Monument Way, Concord, CA
Morris and Lee Co.*		Eccen Cam/ Ext Vane	1959	Buffalo	Modified Norge Rolator refrigeration compressor, for use as low cost vacuum pump. Discontinued in early 1970s.
Nelson Vacuum Pump*	Nevaco	Oval Cam/Ext Vane, Belt, Eccen Cam/Elas Imp, Direct	1927 1966	Berkeley	Bought by Ace Pump, Memphis, who no longer produces product
Precision Scientific*	PSCO	Rotary Vane Belt & Direct	1957	Chicago	Bought by GCA Corp., then in 1996 by Jouan Inc. in Winchester, VA, who no longer produces product
Red Point Corp.*		Rotary Vane, Belt	1955	Glendale, CA	Discontinued pump line mid-70s
Robinair Mfg Corp. of	Robbi	Rotary Piston, Belt & Direct, Rotary Vane, Direct	1971 1982	Montpelier, OH	Original pump was Rotary Piston, present is Rotary Vane, Robinair now a div SPX: Robinair SPX Corporation 1224 Robinair Way, Montpelier, OH 43543
FJ Stokes MFG Co.		Rotary Piston, Belt Rotary Vane, Direct	1936 1982	Philadelphia	Purchased by BOC Edwards, now: Stokes Vacuum Div 5500 Tabor Rd, Philadelphia PA 19120
WM Welch Scientific	Duo-Seal	Rotary Vane, Belt & Direct, Gerotor, Direct	1934	Chicago	Welch merged w/EHSargent, then went private, then bought by Thomas Ind, now: Welch Vacuum Technology Div 7300 N Linder Ave, Skokie, IL 60077

*no longer in business, or producing vacuum pumps