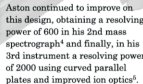


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Physicists soon recognized that improved resolving power for the mass spectrograph depended upon developing some means of energy focusing of ions. The primary means of ionization at the time was the gas discharge tube which created ions with a very large spread of energies. This led to broad diffuse mass spectral lines, with resolving powers on the order of 50 or less. Physicists soon recognized that improved resolving power for the mass spectrograph depended upon developing some means of energy focusing ions.

**ENGLAND** Aston at Cambridge was among the first to employ the addition of an electric sector in the ion optics of his mass spectrograph<sup>9</sup>. In his first instrument, ca 1919, the electric sector consisted of a set of parallel plates immediately after the ion source in the ion optical path. One plate was at ground and the other was at voltage. This device increased the resolving power to about 130.



Aston, F. W. A positive-ray spectrograph *Phil. Mag.* 1919, 38, 707-715

Plates  $J_1$  and  $J_2$  act as an energy spectrometer. By rotating the Slit  $S_5$ , one can select ions with a small energy distribution. It is interesting to note that Aston's instruments had accelerating potentials up to 48 kVdc and the photo

plate was nearly linear in mass. With his 3rd instrument, he was able to accurately determine the isotopic weights and packing fractions of over twenty atomic species, some for the first time.



**GERMANY** Mattauch & Herzog in 1934<sup>10</sup> at the University of Vienna described the complete theory for which all arrangements of a radial electric field and a homogeneous magnetic field could be arranged to obtain both direction and velocity focusing in a mass spectrograph. Later, in 1936, Mattauch published<sup>11</sup> the design of an instrument based on this work with resolving power of 1750.



Josef Mattauch with Harold Washburn at the Consolidated Engineering Corporation in Monrovia California in 1957. CEC later manufactured and sold an instrument based on the Mattauch Herzog geometry in 1959



The Harvard mass spectrograph based on this ion optical geometry had a resolving power in excess of 10,000. The electrostatic sector voltages of  $\pm 1215$  Vdc were supplied by two sets of twenty seven 45 volt batteries!

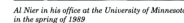
**JAPAN** Workers in Japan at Osaka Imperial University<sup>12</sup> used an instrument of the Bainbridge Jordan design to refine the isotopic weights of chlorine, argon and iron in 1940. This instrument was subsequently moth-balled in 1943 and after World War II was reinstalled by Ogata and Matsuda with a resolving power of 58,000<sup>13</sup>. Matsuda went on to be a major force in the design of high resolving power magnetic sector instruments in Japan reporting in 1956 an instrument capable of 500,000 resolving power<sup>14</sup>.

[illegible]

The two sector mass spectrometer based on this work was the inspiration for several commercial instruments made and marketed from the late '50s to the present.

could meet or exceed the resolving power of the mass spectrograph. An instrument based on this design was built in 1950 by Nier and Roberts.<sup>16</sup>

As the result of the high resolving power mass spectrometer design first constructed by Nier and coworkers, the idea that accurate mass determination of organic molecules could be used as a means of ascertaining their elemental composition led to the development of a 90° electrostatic sector 90° magnetic sector instrument by Metropolitan Vickers, a British company. The prototype of this instrument, the MS-8 was placed in service with Beynon, and proved to be such a success that commercial versions of the instrument, known as the MS-9, were subsequently made and sold.



As the popularity of the MS-9, a mass spectrometer grew, it began to compete with the CEC 21-110, a mass spectrophotograph, for the accurate mass determination of organic compounds. The MS-9 used an electron multiplier detector, amplifying the minuscule ion current at the image slit as the mass peak was scanned across it. The 21-110 had a photo plate detector which summed the ion current at each mass for the duration of the analysis. Consequently, the mass spectrophotograph was considered to be more sensitive than the mass spectrometer, since all of the ions formed during the analysis were integrated at the photoplate while only a fraction of the ions for any given mass were detected at the electron multiplier.

The drawback of the plate used in the mass spectrograph was that it had to be developed in a dark room and subsequently scanned by a photo comparator to process the mass spectral data into electronic form. In the mass spectrometer, the mass spectral data was available in electronic form in real time, as the instrument was being scanned. However, the only way to obtain an accurate mass with the latter instrument was one mass peak at a time by a tedious process known as peak matching. The competition between the mass spectrograph and the mass spectrometer for high resolution applications was not long, but once computer-based data systems were developed that could process the electronic signals from the high resolving power mass spectrometer, it began to dominate the market for that application.

Scientists in Germany and Japan joined those in the United States and the United Kingdom in competing to develop a variety of double focusing instruments with ever increasing resolving power. Important milestones in the development of double focusing analyzers for some companies are the time of flight mass spectrometer, the advent of ionization methods such as electron impact, and the development of biomolecules, having a large mass range become an important requirement in sector instrument design. The electrostatic analyzer plates on display are from a Vacuum Generators ZAB-SE double focusing electrostatic sector mass spectrometer. The ZAB-SE is a double focusing instrument and analyzer concepts have superseded the sector design for achieving high resolving power with a large mass range. While double focusing sector instruments are no longer 'King of the Hill' as they were for several decades, they continue to provide useful data for a broad range of applications, both in