

Towards a history of the international industrial gases industry

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Business and economic historians have long since concerned themselves with the emergence and development of the industries of the so-called “second industrial revolution” and their component companies. From David Landes’s classic study, *The Unbound Prometheus*,¹ to some of the later work of Alfred Chandler (e.g. *Shaping the industrial century: The remarkable story of the evolution of the modern chemical and pharmaceutical industries*),² chemical producers, electrical goods manufacturers, and other “research-intensive” industries and companies have figured prominently in scholarship on the emergence of the modern enterprise and the modern economy.

One of the industries of the second industrial revolution has been virtually ignored in this scholarship to date, however: the industrial gases industry, aptly termed the “invisible industry” in a short overview published by its manufacturing association,³ is not mentioned at all in Landes’s overview and rarely if ever in other works. There is only one book-length history of it, not written incidentally by an historian, but by a practitioner, and concentrating therefore heavily on technical aspects of the industry.⁴ A very few books on specific companies in the industry written by professional historians

¹ Cambridge: CUP, 1969, 2nd ed. 2003.

² Cambridge, MA: Harvard University Press, 2005.

³ IOMA, *The invisible industry: The story of the industrial gas industry* (Cleveland, OH: IOMA, 1997).

⁴ Ebbe Almqvist, *History of industrial gases* (New York: Kluwer Academic/Plenum, 2003).

exist, all published since 1990.⁵ This relative neglect is somewhat ironic in that industrial gases, produced by a handful of specialised firms, have been critical to enabling innovation and development in more prominent industries ranging from chemicals and semiconductor manufacturing to steel production, oil refining and food processing. We are currently seeking to remedy this scholarly deficit by researching and writing a history of the industrial gases industry through business history of its component firms from its inception in the late 19th century to the present. It is a four-year project which will result in a monograph.

The industrial gases industry: Key characteristics

But what are industrial gases, and what are some of the key characteristics of the industry that produces them? There are a number of different gases, but essentially one set of them involves individual gases of greater or lesser purity drawn from the air—oxygen, nitrogen, argon, neon, etc.—or from other sources—e.g. hydrogen from steam or natural gas and helium from natural gas—and one set involves combinations of individual elements using ingredients from a variety of sources—e.g. acetylene, nitrous oxide, carbon dioxide. The technological systems involved in producing, handling, delivering, and storing such gases can range from relatively straightforward and involving modest capital to extremely complex and capital-intensive. Air-separation units, for instance, have tended from the beginning to be capital- and energy-intensive, with little cost for labour (and of course no cost whatsoever for raw materials!⁶).

⁵ Andrew J. Butrica, *Out of thin air: A history of Air Products and Chemicals, Inc., 1940-1990* (NY: Praeger, 1990); Hans-Liudger Dienel, *Linde: History of a technology corporation, 1879-2004* (Basingstoke: Palgrave Macmillan, 2004); Jörg Lesczenski, *100 Percent Messer: The return of the family firm* (Munich: Piper, 2007).

⁶ AGA, *Annual Report*, 1982, pp. 8-9.

Although gases had been produced for some time beforehand, the modern industry's origins are conventionally dated to 1895, when Carl Linde registered a patent for liquefaction of air into its two largest components, oxygen and nitrogen. The Linde process fundamentally altered what had been to that point a small-scale, niche industry into larger-scale one. Linde's invention was quickly followed by a number of other improvements and/or alternative processes, and the industry grew rapidly into the early 20th century, by which time most of the major players in it had been founded. These included Linde, Linde Air Products (incorporated in the United States, later Union Carbide Corporation Linde Division and then Praxair), British Oxygen Company (BOC), Messer, Taiyo Nippon Sanso, Liquid Carbonic, AGA, and Air Liquide. Five of these companies are still in independent existence today (with the others having been acquired by/merged with one or another of these five). Not only do they continue to exist, the five are also prominent among the seven "Tier 1" industrial gases firms today which together controlled about 75 percent of the world retail gas market in 2006; three of the pioneer companies (the Linde Group, Air Liquide, and Praxair) accounted for well over half of the world retail gas market in that same year.⁷ The other two current-day top-tier firms, by the way, were founded later, something we shall return to shortly.

Here, then, we can see some of the key characteristics of the industry and why it is of great interest for the business historian. For one thing, the importance of being an early entrant into the industry is clear. Entering early did not necessarily entail survival—most of the firms mentioned above have been swallowed up—, and it has been possible for companies to enter later (e.g. the two "others" in the seven tier one companies, Air Products [1940] and Airgas [1982]), but there has been a startling level of continuity in

⁷ Dr Peter Vocke, "The world market for industrial gases," presentation in Munich, 8 October 2007.

the key players in the industry over more than 100 years. A second key characteristic is that the industry is oligopolistic. Like the tyre industry or the petroleum industry, a handful of very big players dominate production and sales of industrial gases. Like those other industries, industrial gases have involved complex and shifting commercial and technological competition and co-operation. From the First World War until the late 1950s and 1960s, and again like these other industries, there tended to be fairly strict market segmentation based on geography and “spheres of influence”. BOC, for instance, was responsible for 98.5 percent of the British oxygen market and had the same share in the market for acetylene in 1954.⁸ In fact, until challenged by the arrival of American-based Air Products on the British scene in the late 1950s, BOC “was widely known as ‘the Ministry of Oxygen’.”⁹ BOC held a similarly strong, practically monopolistic position in British colonies and later the Commonwealth. For instance, in the early 1960s, BOC’s majority-held subsidiary in India controlled about 90 percent of the oxygen and acetylene market there, and nearly 100 percent of the market for argon and hydrogen.¹⁰ There were, however, some hotly contested markets, such as the United States, especially before 1914 and after 1960, and more recently China. And there have been intrusions into previously secure “spheres of influence”, especially since the 1950s. In these areas and time periods in particular, the dynamics of oligopolistic industries in general appear to have held sway: Organisational, technological, and other innovations or changes by one key player were keenly observed, sometimes anticipated, and often quickly imitated, by the others. It should be noted, however, that despite the oligopoly, and up to the present

⁸ UK Monopolies and Restrictive Practices Commission, *Report on the Supply of Certain Industrial and Medical Gases* (London: HMSO, 1956), p. 7.

⁹ “International gas man,” *Industrial Management* (February 1972): 38-42, quotation from p. 39.

¹⁰ “45 Years Ago: Air Products enters Indian oxygen game,” *ICIS Chemical Business*, Vol. 2, Issue 49 (15 January 2007), p. 32.

day, there has been a persistent and significant part of world and/or regional market shares in the industry which has been occupied by small and medium-sized enterprises (SMEs). How and why this has been possible are questions we are wishing to explore in the project.

Thirdly, the industry has tended towards concentration. This was true even in its earliest days, when a large number of entrants failed, were swallowed up by others, or consolidated to form larger units. Beginning after World War II, and especially since the 1990s, this development has continued apace. Linde, for instance, acquired the Swedish AGA in 2000, and BOC in 2006, the latter doubling the Group's size and giving it about the same market share as Air Liquide. (Air Liquide, together with American-based Air Products, had withdrawn an offer to acquire BOC in 2000 following a negative report by the U.S. Federal Trade Commission.¹¹) These two largest firms, Linde and Air Liquide, controlled a total of about 40 percent of the market by 2006. Again the caveat is that some smaller and medium-sized firms continue to exist, indeed to thrive, in this environment. And once again, one avenue of research will be to uncover how and why this is so.

A fourth characteristic of the industry has been the diversification of the interests, technologies, and businesses of its component companies, which seems to have become more pronounced through time. There is a wide range here, however, both between individual companies and for a particular company through time. For instance, Air Liquide has the reputation of being the most heavily focused of the top tier companies on the gases business, but in 2005, only 10.3 percent of its revenues of over €1.4 billion came from its "gas and services" division. Still, an additional 2/3 of its revenues in that year

¹¹ Data Monitor Company Profile: Air Liquide SA, Reference Code 7892, June 2006, p. 22.

came from closely allied areas, i.e. (primarily gas and chemical plant) engineering and construction, but also welding.¹² In other words, this is clearly an example of a company pursuing a strategy of closely connected diversification. But others have been far less focused, at least at times. AGA, for instance, made stoves, lighthouses, and radiators, indeed “everything but the kitchen sink” in the 1950s and 1960s before refocusing on gases in the 1970s.¹³ BOC was involved in manufacture of siphons, vocational computing training, and distribution of chilled foods for Marks and Spencer.¹⁴ What we hope to ascertain is why these diverse strategies of diversification were pursued within a given company at a given time, how the strategies changed through time, and what impact strategic choices in relation to diversification had upon competitiveness and profitability.

All of these characteristics are not peculiar to the industrial gases industry, although it is perhaps an extreme example of each of them. A series of other characteristics make it more unusual, certainly taken together, and especially taken together with those just outlined. For one thing, there is a strong and significant tension in the industry between the need to produce gases fairly locally—most of them don’t travel well—and its international reach. Secondly, there is an enormous variation in the prices commanded for the industry’s products. Thirdly, there is almost no scope whatsoever for product differentiation for particular gases of a particular level of purity. High-purity argon of a given standard is identical, whether produced by Air Liquide, Linde, or any other company in the industry. Competitive advantage comes through service, support, and applications. Finally, related to this point, one of the sources of barrier to entry to the

¹² Data Monitor Company Profile: Air Liquide SA, Reference Code 7892, June 2006, p. 16.

¹³ “The Gas Company,” *Eurromoney* (September 1984), p. 8.

¹⁴ BOC, *Around the World in 100 Years* (London: BOC, 1986).

industry is the heavy investment necessary for developing capabilities not only in technology, but simultaneously in transport, logistics, and marketing.

The research project: questions, design, and early findings

Our research project, which started at the end of 2007, is due for completion in August 2011, and has as its main aim the production of a definitive monograph on this generally neglected, but extremely important, industry from its inception in the late 19th century to the beginning of the 21st. It will explore the industry's dynamics in national and international contexts for the most part through study of individual firms, insofar as possible using archival materials. Four main questions will provide a focus for the research:

- What factors have shaped the competitive strategies of key firms in the industry over time, and how successful have they been?
- How have the barriers to entry into the industry changed through time, and what factors have determined the extent of concentration in it?
- What roles have evolving markets and changing demands of customers played in shaping the industry's development?
- What have been the sources of innovation in the industry, and what role have innovation and intellectual property played in competitiveness in the industry?

Clearly, since we would like the final monograph to be readable as well as read, it cannot be overly long. We have budgeted 400 printed pages for it, which will be manageable for the reader, but perhaps more challenging for the writers. After all, after the introduction and conclusion as well as bibliography are deducted from this, there is

not a lot of space to do justice to the complexities of the industry's development over more than 100 years, let alone all important firms and key issues. So we are going to have to be highly selective, which, given the vast amount of material we have collected already, will be a challenge, but the good news is that very good material is available, and more is being made available on a regular basis—most of the key firms in the industry, as well as some SMEs, have been willing to grant access to archival material, printed primary material, and/or interview partners.

Based on what we have done thus far, we are planning to organise the monograph into five parts, arranged chronologically, within which 12-13 substantive chapters will deal with key themes. Part one will deal with the origins and initial definition of the industry, looking at the pioneering firms, the technologies that enabled growth, and the emergence of additional markets beyond lighting, “limelight”, and medicine, especially in welding and synthesis technologies. Strategic takeovers, initial forays into the American market (this was a largely European industry at first), and co-operation and disputes in relation to intellectual property are three of the key areas we will explore in detail.

Part two will explore the impact of the First World War and the economic dislocation thereafter on the industry. Linde Air Products became a division of the Union Carbide Corporation in 1919, for instance, a legacy of the war. Again, new markets (e.g. airships, new medical areas, synthetic oils and other synthesis technologies) and technologies (allowing more efficient heat exchange, better storage, better purification, and also heightened rare gas recovery) were crucial, as was the consolidation of spheres of influence. In regard to the latter, we will compare in some detail the strategies of the

two large European imperial “champions”, i.e. Air Liquide and BOC. Both engaged in consolidating domestic markets, but also expanding internationally into their respective imperial markets. Co-operation as well as competition will be explored, not least through cartel and other arrangements to attempt to stabilise markets.

We begin part three in 1940, for reasons we will come to shortly. It focuses in particular on the industry’s role in the emergence of high-tech industry in the post-World War II period in the context of the “Third Industrial Revolution” (involving the industry playing a key role in, among other things, plastics, electronics and semiconductors, oxygen steel, and oil refining). The starting date for the chapters in part three is significant because it was when Air Products was founded, the first major new entrant into the industry since the early 20th century. How it overcame barriers to entry will be one of the areas we explore in detail. The impact of the war was again important, not only in terms of technology, but also in terms of organisation and long-term development. In the context of the American-dominated western world post-war order, for instance, technology transfer became easier, but this industry was also faced with challenges to long-held organisational forms and assumptions, not least through competition legislation and policies, which undercut some of the arrangements that had characterised the period before the 1950s. It is no accident that BOC’s virtual monopoly position in the industry in Britain began to be threatened late in that decade, first through investigation by the Monopolies and Mergers Commission, and then at the very beginning of the next decade by an American entrant into the British market.

Two key characteristics of the period which followed (dealt with in part four, which covers 1960-1990) were soaring demand and the beginnings of real globalisation.

The United States will be a key focus of our investigation here. Massive and growing demand for oxygen was accompanied by even faster growth in demand for nitrogen, production of which outstripped that of oxygen for the first time in 1980, presaging developments in other highly industrialised countries. The growth was facilitated by new technologies in the industry—tonnage plants, better insulation and storage, pipelines, and so on—which enabled demand to be met. But the companies in the industry were also forced to enter into strategic alliances with chemical firms owing to new process technologies (e.g. membrane technology).

The U.S. case will also allow us to explore expansion strategies for some of the established players, such as BOC, which acquired the American Airco in 1978. And it will again allow exploration of how barriers to entry were overcome: Airgas, one of the first tier players in the industry today, is also by far the youngest, having been founded only in 1982. Finally, we will begin to explore in detail the story of how SMEs were able to continue to compete (or not) in this context, comparing the cases of an American and an Italian firm in the context of American and Italian SMEs in the industry in general.

In part five we will try to unpack some of the developments of the industry in the period 1990-2007. It has been a period of enormous consolidation among the large players, not least because of ongoing globalisation and the emergence of new markets and challenges in eastern Europe, the Asian subcontinent, and East Asia, not least China. Again, technological change will be an important part of the story, not least owing to the growing importance of on-site plants and technology and intellectual property policies. But we will also look at the broader context for competitiveness. What organisational and

other systems have been developed to give a competitive edge? Again, how have niche players managed not only to survive, but even to grow, in this environment?

In conclusion, our aim in this project is not only to make this heretofore “invisible industry” more visible, which is of value in itself, but also to study it for its more general implications for understanding international business history, in particular issues relating to business strategies and their development over time, technology and innovation, and behaviour of oligopolistic industry.