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CHEMISTRY THROUGH THE ‘TWO REVOLUTIONS’:  
CHEMICAL GLASGOW AND ITS CHEMICAL  
ENTREPRENEURS, 1760-1860\*

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*Introduction*

The principal focus of this essay, the town of Glasgow and the chemical works of St. Rollox, is local, but has a general resonance, for St. Rollox has at times been regarded as a paradigmatic case of industrialized chemical production within the encompassing orbit of the Industrial Revolution. Here, inarguably it seems, are to be found the kinds of research-based, knowledge-induced technical innovation, entrepreneurship, growth rates, scale transformations, employment and wage patterns, which allow assimilation to some or other historiographical normativity of industrialization, at least in British terms. One may note in passing here, that although St. Rollox’ development is known well enough in outline, and with some quantified information, this is not known directly from archives of company records, or from any detailed history of the company, for few such records, if they still exist, are currently available to the historian.<sup>1</sup> Information is derived rather from sources such as the *New Statistical Account of Scotland*, and other contemporary observers.<sup>2</sup> Some informal local or parish histories, and biographical and family-history treatments of the two principal figures of the early history of St. Rollox, Charles Tennant and Charles Macintosh are also useful. The most recent and conceptually sophisticated, albeit relatively brief treatment of St. Rollox within history of chemistry is in fact composed from research by undergraduates at UCL, students of Hasok Chang and Catherine Jackson engaged in writing the ‘Life of Chlorine’.<sup>3</sup> They offer a critique of ‘technologically determinist’ and simple, linear approaches of older writers on the history of chemical technique, which saw progressive innovation from authenticated chemical science, to technological advance, to industrial production, as the key to providing credible narrative intelligibility to the history of chemical and industrial development in chlorine bleaching. The UCL students proceed to recommendation of a more ‘rounded’ SST approach, emphasizing the complex, contingent and feedback looping elements characteristic of understanding based upon ‘social shaping of technology’.

The approach adopted in this essay has some kinship with this advocacy, but has additional characteristics. Firstly its most acute focus is upon ‘situation’, the town of Glasgow, and the industrial site of the St. Rollox Chemical Works within it. Importantly, it equally emphasizes contemporary Glaswegian sites of chemical production other than St. Rollox, and the infrastructural development of educational and collective commercial institutions within the town. Secondly, it focuses upon three chemical-entrepreneurial figures, Robert Townsend of the Port Dundas works, and Charles Tennant and Charles Macintosh, at the centre of St Rollox chemistry and industrial expansion. The latter pair provides two further reasons for attention. Both, as young men, pre-St. Rollox, worked in a pre-industrial setting, the ‘age of manufactures’ or of ‘proto-industry’, and their careers therefore offer the opportunity of tracking the transition of practical chemistry and its techniques from pre-industrial through to thoroughly industrialized

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settings, a period also coinciding with the rapid sequence of development in chemical science alluded to in this Section's Introduction.<sup>4</sup> Because some narratives of industrial revolution reflexly emphasize qualitative, ultimately discontinuous change, these two careers thus also provide an opportunity for critical attention to that historiographical reflex, with respect both to practical chemistry, and to industrialization. Further, as 'entrepreneurs of the Industrial Revolution', Townsend, Tennant and Macintosh, in their very different ways, repay analysis of the varied and contrasting forms of chemical-entrepreneurial activity they exhibited. This in turn will allow critical reflection upon the vocabulary of technical and economic 'innovation', and more particularly, upon contemporary models of entrepreneurship which preoccupy economic historians. Are chemical entrepreneurs easily absorbed by such models as further exemplars, or might they induce attention to more discriminating taxonomies, more varied modalities, of entrepreneurship?<sup>5</sup>

### *1. A Chemical Behemoth*

The St. Rollox Chemical Works, owned and operated by Charles Tennant and Co. in Glasgow, has often been described as being, in its mid-Victorian heyday, the largest in Europe, if not the world. The size of the site, increasing from 2.25 to at least 15 acres; the number of its workers, at least 500 in the 1830's, increasing to at least 1500 by the 1860's;<sup>6</sup> the volume of its output, a 200-fold increase from 50 tons in the first year of bleaching powder production, approaching to ten thousand tons by 1870, with massive per ton cost savings along the way: by 1825, production cost had fallen five-fold.<sup>7</sup> The annual tonnage of the coal required to maintain its furnace operation, thirty thousand tons by 1832, approached fifty thousand tons by the 1840's. Such figures are indeed quantitatively impressive, and demonstrate one vector of the company's overall expansion from its foundation in 1797 through to the death of Tennant in 1838, and to the erection in 1842 of the culturally symbolic and vista-dominating landmark 'Tennant's Stalk', so-called, a towering chimney with a 50 ft. base, 450 ft. high. It was, at that moment in time, the fourth tallest human-made structure on the face of the planet, possibly aided in its design by the young John Macquorn Rankine, civil engineer, heat-engine specialist, thermodynamicist, and later Regius Professor of Civil Engineering at the University of Glasgow.

Size is however often a matter of relative judgement, and parameter-dependent. The economic historian, for instance, may wish to fix upon financial elements, such as annual financial turnover, rates of profitability, inward investment and the like, as opposed to physical extension of site and other physical detail. There is a point to such selectivity. Site-wise a large bleachfield might compare in acreage with early St. Rollox, indeed there was one such in Glasgow, but its financial parameters would have nonetheless stood in stark contrast. One might alternatively think of employment size, for a large site does not of necessity employ large numbers (think again of the bleachfield). There is also interesting international comparison to be made on the question of size. The Gunpowder Manufactory run by the British military in Ichapur, India, employed more than two thousand workers, at least triple the number of St. Rollox workers in the 1820's, and at a considerably earlier date. Arguably, the Indian workers were also in some terms (working conditions, insurance scheme), better off than the St. Rollox workforce, predominantly low-paid, Irish immigrants lacking unionization. The Ichapur Indian workforce might also be held to be both more specialized and more skilled.<sup>8</sup> Employment-wise, therefore, we would calculate St. Rollox at less than half the size of Ichapur, which, though mono-productive, unlike St. Rollox, was indisputably chemical, and British-owned. Ichapur might also remind us that, during the eighteenth century, and into the nineteenth, before the full advent of the fetish of private ownership and individual entrepreneurial endeavour coincident with the industrial revolution, the employer with the highest number of workers engaged in manufacturing, on the largest sites, was the

government, in particular the Army and Navy offices, with their extensive dockyards and munitions works.

St. Rollox originated as manufacture in 1797 devoted to chlorine bleaching, sited in a semi-rural rather than central urban location, north of Glasgow, close to the newly completed Monkland Canal, constructed for transport of coal and ironstone from the nearby Lanarkshire coalfields, and connecting with the Forth-Clyde Canal. This accessed the rivers, Clyde for the west coast, Ireland and Atlantic, and Forth for the east coast and North and Baltic seas, and the English Channel. Tennant firstly used a Berthollet chlorine bleaching liquor, then modified with the addition of lime (as opposed to potash). The move to the Tennant-Macintosh patented chlorine bleaching powder in 1799 was the key element in St. Rollox' early expansion, and the powder remained an ongoing profitable staple of production throughout our period and beyond. The site also diversified internally, additionally producing sulphuric acid and soap, and after the abolition of salt importation duty in the early 1820's, Leblanc process soda, both ash and a lesser amount of crystal. Physical plant grew, and was improved, with expensive installation of platina vats (instead of lead) for concentrated vitriol, more furnaces, chimneys, warehouse storage, canal basin, and railway terminal in 1831 (see *Illustr. 2*, p. 21, with its happy picnickers). Tennant's had a small London branch of the company, and added an acid works at Carnoustie in Fife. By the 1850's the company had its own on-site cooperage, a foundry for equipment-making, and interests in local coal mines. The central chemical works alone had come to occupy thirteen acres. Tennant also began purchase of sea-going schooners, the basis by 1848 of the largest mercantile fleet of ships on the river Clyde, with steam vessels for the London and Baltic trades, and coastal sailing vessels for limestone importation (Ireland) and sulphur (Italy).<sup>9</sup> St. Rollox site-expansion was spectacular, but, through Tennant's relentless application, it became in local, national and international terms also geographically tentacular, by rail, and by water---thus Leviathan accompanied Behemoth. After our period, there would be further expansion, to Tyneside with a very large alkali works, explosives in Ayrshire (with the aid of Alfred Nobel), and to Spain, with the acquisition of the Tharsis copper mines and sulphur production, initiated with a 500-strong imported Scottish labour force.

Contemporary perceptions of St. Rollox certainly recorded its massive productive, economic presence in the north of Glasgow. J.D. Burn, in the late 1850's, was struck by its 'stupendous' size overall, the enormous bulk of the vitriol vats and the chlorination chambers, the mountainous tonnage of heaped chemical raw materials, the hundreds of furnaces, the consequent heat, and the staggering amounts of materials consumed and produced. St. Rollox' impact upon visitors, dutifully noted in quantitatively numerical terms, was equally registered in physical, material terms other than simple tonnages consumed and produced. To Burn's awed perception, and in his thoroughly laudatory account of a progressive manufacture, there was nonetheless consciousness of an infernal working environment, an 'extraordinary labyrinth', a 'devil's den', men 'moving about like spirits in the fitful glare of the furnaces', all dominated by the 'monstrous' dimensions of Tennant's Stalk.<sup>10</sup>

Physically St. Rollox dominated its locality in terms of its gigantism, but there was more to such a presence than physical extension. Its material penetration of the surrounding environment became just as noticeable. George Dodd's description a decade earlier noted size, the wonders of modern chemical production, and also monstrosity, and further emphasized the deleterious working environment produced by the combination of chemical process and large-scale production.

The name of Tennant has just been mentioned: this name is connected with one of the most gigantic establishments--- not merely in Glasgow--- but in the world. This establishment is the St. Rollox Chemical Works, situated on the high ground in the extreme north of Glasgow,

close to the temporary terminus of the Caledonian Railway. From whichever side we approach it, we are forcibly struck with its vastness: area, number, height--- all are there; the area of the whole works, the number of chimneys, and the height of the giant 'stalk', as factory people call the great chimney. From salt and sulphur, by the beautiful combinations and re-actions which modern chemistry points out, a whole series of useful substances may be produced; and it is to these substances that the operations of the St Rollox Works are mainly directed. Common soda, carbonate of soda, sulphuric acid, muriatic acid, chlorine, bleaching powder--- all are connected by a chain of affinities with those two plentiful and valuable substances with which nature has enriched us. When the costly metal *platina* was first used for crucibles and vessels, in the manufacture of acrid liquids which would destroy most other substances, one single apartment at the St. Rollox works was fitted with platina vessels which cost £7000! But it is not these products alone: soap is made on a vast scale at the St. Rollox Works; and other drugs and chemicals are also manufactured. The buildings and furnaces are perfectly bewildering.... They are, necessarily, black and dirty; and some of them are as infernal in appearance as we can well imagine any earthly place to be. The heaps of sulphur, lime, coal, and refuse; the intense heat of the scores of furnaces in which the processes are going on; the smoke and thick vapours which dim the air of most of the buildings; the swarthy and heated appearance of the men; acrid fumes of sulphur and of various acids which worry the eyes, and tickle the nose, and choke the throat; the danger which every bit of broad-cloth incurs of being bleached by something or burned by something else--- all form a series of *notabilia* not soon to be forgotten. The buildings form an immense square, from which shoot up numerous chimneys. Many of these chimneys are equal to the largest in other towns; but they are mere satellites to the monster of the place--- *the chimney!*<sup>11</sup>

The accounts of Burn and Dodd converge in obvious ways with respect to St. Rollox gigantism, monstrosity, and the bewildered observation of the novice observer. They diverge however, on the working environment, seen by Burn as no worse than other industrial concerns, and not really injurious, but acknowledged by Dodd as dangerous and unhealthy. Burn has one additional point worth noting, in the contrast he draws between the rural situation of pre-industrial chemical bleaching, and the industrial. He did this curiously, by contrasting his reaction to illustrations seen in his younger years, of attractive, loosely dressed rural nymphs pictured in rural-manufacturing circumstances, toward whom--- how might one put this?--- his youthful heart warmed (see Illustr. 1, p. 20) He retained his conviction that, nonetheless, industrialization was, in comparison, undoubtedly progressive.<sup>12</sup>

This progressive narrative registered in educated, popular bourgeois and upper-class reading, whereas one needs to look to demotic and musical working class expression for registration of dissent from the progressive narrative, and contrasting emphasis upon working conditions. Tennant and Co. appeared in Walter Scott's *The Antiquary* as follows, the scene set among the town gossips in a postmaster's house in a seaport town on Scotland's north-east coast:

"Eh, preserve us, sirs" said the butcher's wife, "there's ten eleven, twal letters to Tennant & Co.—thae folk do mair business than a' the rest o' the burgh".

The Tennant's correspondence is subject of further discussion a few pages later, in authorial voice:

Many, strange, and inconsistent, were the rumours to which their communications and conjectures gave rise. Some said Tennant and Co. were broken, and that all their bills had come back protested--- others that they had got a great contract from the government, and letters from the principal merchants of Glasgow upon a premium.<sup>13</sup>

The letters under speculative discussion are arrivals, by the Edinburgh post, and they therefore, within the fiction, indicate the presence of a Tennant and Co. representative in the town. They also indicate a speculative knowledge of Tennant and Co.'s status and commercial development, the

possibility of a government contract, and of the commercial manoeuvring which might accompany such a contract. Scott, the most successful novelist of the time, saw fit, writing in 1815-16, to provide local colour for provincial Scotland by using Tennant and Co.'s business organization and commercial prospects as items of gossip recognisable to his readers, a readily intelligible sketching of common communicative life, and to that extent a recognition of Tennant and Co.'s rising and pervasive presence in Scotland's commercial culture, some eighteen years after its foundation.<sup>14</sup>

A contrasting view of St Rollox is found in the following verses, recited by Hugh Aitken Dow at a Royston School reunion in 1875. The Royston School was founded by Tennant's for the children of their workers, so the strong likelihood is that Dow was a local resident, and had been a St. Rollox chemical worker, perhaps as early as the 1840's.

A busy, noisy clam'rous spot,  
Where trees, nor flowers nor fields are seen  
Where men by day and night are wrought  
And holy calm hath rarely been.

Where fragrant zephyrs never blow  
but smutty is its atmosphere,  
when rain falls dense and winds are low  
its sulphurous elements appear.

When winds blow south, a cloud by day  
it may at once be seen and felt  
for smarting eyes then own its sway  
through muffled noses then 'tis smelt.

There fiery pillars, gleam at night  
from hooded chimneys, tow'ring high  
and cast their vivid, fork'd flames bright  
up to the troubled murky sky.

There Vulcan's [forge] would fail to match  
the Glasgow ironworks polka blows,  
his lurid fires would pale and dim  
'fore Tennant's countless furnace glows.<sup>15</sup>

Invaluable as a direct comment by a chemical worker, Dow's verses confirm the oppressive, sooty and sulphurous atmosphere of the St. Rollox Works and its surroundings, and also its physical effects. A nether-world is again invoked with the figure of Vulcan, but, the verses insist, even the god of fire, forge and metallurgy can no longer compete effectively. At a later date in the century, the nose of one of St. Rollox' chief chemists, nicknamed Sniffer Crystal, had been eroded, by his constant olfactory occupation of gauging chemicals.<sup>16</sup> If St. Rollox was comparable with contemporary English chemical works, then indoor workers, in the vitriol rooms say, the soda sheds, or the chlorination chambers, would after a number of years be moved to work outside in the yards, so deleterious were the effects of working the chemical processes.<sup>17</sup> Chemical workers were of course acutely aware of such specific occupational consequences, and of occupational life expectancy.

If a man goes to the works young he will be past working before he reaches forty years of age.... For instance, you will easily know a chrome worker from the fact that, as a rule, the bridge of his nose is completely eaten away. In some cases, where they have not been so long

employed amongst the chrome, you will notice that the nose is often partly decayed and in holes, and it is very seldom that you will find a chrome worker who is not more or less affected in this part.<sup>18</sup>

It is difficult to avoid the conclusion that St. Rollox' general environmental and particular physiological impacts were pervasive, oppressive and unhealthy. The chimneys poured smoke, soot and chemical fume into the sky, a subject of sarcastic pictorial comment (see *Illustr. 3*, p. 21, 'A Clear Day at St Rollox'). Liquid chemical waste was put into the canal and other water-courses, solid waste simply piled on neighbouring land. The local atmosphere was impregnated with chlorine and sulphur acidic fumes. Local residents brought legal complaints.<sup>19</sup> In terms of an Aristotelian material cosmos, St. Rollox' coverage was absolute. Earth and water absorbed its chemical waste. The air was increasingly contaminated by its carbon and gaseous exhalation, the fire of the furnaces flamed incessantly, and the ethereal sky was occluded by the smoke, rising to join Glasgow's often low cloud ceiling, whose frequent rain returned fractions of the furnace carbon and acidic fumes to earth.

None of this is of course particularly surprising. We are long accustomed to industrial revolution narratives of massive and continuous output expansion, technological innovation, factory labour concentration and exploitation, urban pollution, disease and crowded, squalid housing. The Garngad, the area around St. Rollox excelled also in the latter. An accompanying, progressive 'science and technology' narrative, old-fashioned perhaps, but still exerting influence, might be briefly sketched as follows. In Sweden, the chemist Scheele, one of chlorine's discoverers, observed the substance's bleaching properties, with experimentation on plant materials. In France, Claude-Louis Berthollet, intrigued with these properties, undertook further experimentation, which resulted in his origination of the innovative technique of chlorine-based bleaching, eventually producing a chlorine liquor bleaching agent, which he proceeded to publicize to French bleachers. James Watt, a colleague of Berthollet's, learned of his new process, which, although difficult and dangerous to manage, possessed considerable potential advantages over existing bleaching techniques, above all the reducing of cloth bleaching to direct chlorine treatment, eliminating the existing, very lengthy techniques of alternative alkalization and acidification followed by time-and-space consuming exposure to sunlight. It can all, in principle, be moved indoors, and done with the key, newly discovered, liquefied chlorine gas, with cost reduction and labour-process reconfiguration possessed of developmental potential. Berthollet himself was close to the heart of the chemical revolution in France, and its new chemistry of gases. This scientific context had thus produced dramatically innovative technique, publicised through Berthollet's benevolent, philosophical commitment to human betterment, and James Watt, emergent hero of steam-power mechanical technology, either directly or indirectly informed colleagues and compatriots of it when he returned to Britain. Amongst these compatriots were the progenitors of St. Rollox. Tennant and Macintosh adopted the liquor technique with some modification, and commenced the new works with it. Within a few years, they effected a radical improvement in the new chemical technology with a process which produced a powder, and this produced significant further cost savings, particularly in relation to packaging, transport and distribution, the liquor being much heavier, bulkier, and prone to lose its efficacy, than the powder. The technical revolution originating in and accompanying the chemical revolution was now essentially complete, and the result in Scotland was St. Rollox and its economically expansive and culturally iconic, if ambivalent history, forged by the practical chemical acuity and exceptional entrepreneurial abilities of the Tennant and Co. partnership. Such a 'linear' account, neatly enough, conjoins a history of pure science terminology of experimentation and discovery and applied science-driven technological innovation, with the equally significant terminology of innovative industrial entrepreneurship---- a tale of two revolutions, discontinuously instituting modern chemistry and



modern urban industry, whose integration proved to be an unstoppably powerful and transformative historical force, whatever evaluative attitudes historians may have held, and still hold, towards it.

## ***2. Behemoth Deconstructed***

Without denying the factual basis for the above progressivist narratives of chemistry and industry, it is nonetheless possible to use further historical detail in ways which refuse simple endorsement of them, and introduce further resources for conceptualising and narrating the origins and development of key aspects of chemical manufacture and industry, practical chemical technique, chemical science and education, chemical entrepreneurship, and Glasgow itself, within the period 1760-1860. We have long known, for instance, of the very considerable difficulties, of chemical technique, experimental and practical development, of competition and cost, and of hazard to health, which attended attempts to introduce Berthollet's oxymuriatic liquor into commercial production in the late 1780's and 1790's. The extensive and detailed research of Musson and Robinson revealed a lengthy series of efforts, in Lancashire, Nottinghamshire and the west of Scotland, to introduce chlorine bleaching on a commercially viable scale.<sup>20</sup> From Berthollet's original work until the patent application for the Tennant's powder took fourteen years. Those years were filled with further practical chemistry experimentation (including Berthollet's own), numerous trials involving a considerable variety of different technical apparatus (particularly containment vessels for acid and gas, complicated flask arrangements for managing the gas, and a measurement device for gauging bleaching strengths), direct gas-to-cloth treatment, and a number of different chemical additives to liquors to manage both the degree of caustic strength and the respiratory and ocular hazards of working with chlorine. Processes which worked with linen did not necessarily work with cotton. Printed calicos offered further problems. Alkaline addition diluted bleaching efficacy, and transport of bulky, heavy liquor was not propitious. Some became convinced that even with workable and reliable liquor, the whole process would be just too costly for commercial viability. The competitive environment induced levels of secrecy, and of betrayal, among the groups trialling the varieties of new processes. The new processes themselves, if successful, would, it was feared, face further competition from combinations of old-method bleachers, who would co-operate to undercut new-method prices, a particular vulnerability given the anxious cost estimates of new-method trialists. Several competing groups of manufacturing chemists devoted sizeable investment of time and money, convinced of the chlorine route to a radically reformed commercial bleaching. At least three of these groups, each containing experienced bleachers and reputable practical chemists, nonetheless ended in failure, and were obliged to give up on this particular chemical quest. Then when some reliably usable liquors were formulated, and the Tennant's powder emerged as a further reliable option, this by no means signalled the effacement of the older techniques. Some liquor bleachers would still wash, dry, and expose cloth to sun, so there was no sudden and decisive demise of outdoor bleaching grounds. The process of 'innovation' was not simply 'difficult' and 'bumpy'; this really does not capture the reality of the case. It was long-drawn-out, populated with serious financial hazard and a substantial business failure rate; at any given moment within the period, it appeared as entirely contingent, upon a large number of chemical, technical and business variables; and as an historical process it continued to remain incomplete, as the persistence of older methods in tandem with new tended to demonstrate. Any account of the chlorine innovation which focuses simply on the Berthollet discovery at one end and successful powder manufacture at the other is thus prone to ignore the actual historical process of what gets called, and singularized, as 'innovation'. The process was multiple in its attempted novelties, and most of them failed.

Further investigation, details of which now follow, tends to indicate the misleading insufficiency of solely 'revolutionary' narratives, insofar as their underlying concept of change is one confined to radical innovation inducing discontinuous development. It also indicates the inadequacy of accounts of chemical Glasgow's patterns of development focused solely on the pre-eminent case of St. Rollox, and questions the limiting nature of entrepreneurial modelling derived from the paradigm industries of the period, cotton, steam, coal, mechanics and the like.

### *2.i. Chemical Glasgow*

The analysis which follows is geographical in the first instance, based as it is on an excellent Glasgow map of 1828.<sup>21</sup> From our point of view its particular virtue is that it provides clear identities of Glasgow's sites of manufacture (e.g. 'Cotton Works', 'Foundry', etc.) with precise location, and in-principle calculable area occupied by works sites (see Illustr. 4, p. 22). a relevant map section.

It is firstly possible to form a reasonably accurate impression of the range and number of manufacturing concerns. These are given, by their map descriptions, in the table below in numerically descending order.

|                       |     |
|-----------------------|-----|
| Cotton Works          | 22  |
| Foundries             | 18  |
| Distilleries          | 11  |
| Weaving Works         | 8   |
| Breweries             | 7   |
| Dyeing/Printing Works | 7   |
| Quarries              | 6   |
| Potteries             | 4   |
| Steam Corn Mills      | 4   |
| Wood Yards            | 4   |
| Soda Works            | 4   |
| Chemical Works        | 2   |
| Gas Work              | 2   |
| Crystal Works         | 2   |
| Bottle Works          | 2   |
| Saw Mills             | 2   |
| Sugar Works           | 2   |
| Machine Factories     | 2   |
| Water Works           | 1   |
| Acid Works            | 1   |
| Vinegar Works         | 1   |
| Japanning Works       | 1   |
| Coal Tar Works        | 1   |
| Cudbear Works         | 1   |
| Bleaching Ground      | 1   |
| TOTAL                 | 116 |

*Figures compiled from Smith, Plan of Glasgow*

Cotton Works and Foundries predominate numerically, and there are only 2 strictly denominated 'Chemical Works'. To form a more accurate impression of chemical manufacture, we should however add to these the other producers of chemicals, the 4 Soda Works, 2 Gas Works, and the Acid and Vinegar Works; and also the 7 Dye Works and the 1 Cudbear (a dye) Work, the 2 Crystal (leaded glass) Works and the Coal Tar Works, making a total of 21 manufactures where chemical products, crucial chemical processes, manipulation and practical chemical expertise were fundamentally involved. This total still excludes the highly chemical potteries, the refineries, breweries and distilleries, but for chemical completeness with reference to Glasgow, note two further sites, those of the University of Glasgow and the Andersonian Institution, where chemical science was taught. In this overall picture of chemical Glasgow, the sheer size of St. Rollox, (the dark section at the top of the north-west quadrant of map section, Illustr. 4) still predominates as notably the largest manufacturing site in the city; but we should note too that the largest sites generally tend to be chemical, exemplified in addition to St. Rollox by the main gasworks (south-west quadrant), and the Cudbear Works (south-east quadrant). The latter two will also prove to be of particular significance in the developmental pathways we will shortly follow. For the time being, the considerable presence of both cotton and iron manufactures, each of them probably outnumbering chemical manufactures in employment terms, may be noted, along with the extensive areas occupied by chemical production. The textile sector and the chemical cannot of course be functionally separated in local or national terms, in that the expansion of bleaching and dyeing materials which is registered on David Smith's map is directly ascribable to coeval expansion of cotton textile production, locally witnessed by the number of Glasgow Cotton Works, and equivalently in nearby Paisley with the establishment of the large cotton mills of J&P. Coates and Co. The contrast between Glasgow textiles and chemicals at this time is between the large number of smaller units of production in cotton, and the smaller number of large units of production in chemicals, an evident contrast, at least in area, the precise reasons for which I am uncertain. The proliferation of four soda works in addition to St. Rollox is probably explicable in terms of the recent abolition of salt importation duty. It means that, including St. Rollox, up to five Glasgow manufacturers immediately turned their attentions to soda production.

To this additional sense of the comparative placement of chemical manufacture within Glasgow's industrial setting we can add further relevant detail from academic, educational chemistry. Anderson's Institute, founded in 1796 and intended for practical and utilitarian education inclusive of working-class and female participation, numbered in its trustees and professors men with chemical interests. Macintosh was a trustee, as was his business associate John Wilson, whilst William Couper, another friend and business associate, became a teacher of chemistry there.<sup>22</sup> The University of Glasgow by this time possessed a distinguished genealogy of teachers of chemistry, including William Cullen, who worked on both salt and bleaching process manufacture in the 1750's, his pupil Joseph Black who worked on bleaching agents and pursued artificial soda with James Watt, William Irvine with interests in cement, plant chemistry and soil fertility, and a particularly relevant and meticulously quantified, thermometricly-based analysis of the properties of sulphur in heating and cooling.<sup>23</sup> By the time of this survey of the late 1820's, the University's professor of chemistry was Thomas Thomson, an early supporter of Daltonian atomism, a chemist with strong interests also in pursuing the gains made by German analytical chemistry, and making these gains tell with regard to chemical teaching and research.<sup>24</sup> The work of these academic chemists had a variety of bearings upon the practical chemistry of manufacturers, in particular the early attention (1750's-1770's) to alkalization in bleaching and the potential of lime, and Thomson's enthusiasm for Hermann Klaproth's ruthless analytics, which left no residue unexamined.

Some of William Irvine's pupils and associates formed a small Chemical Society whilst in Glasgow, in 1785-7. Their society was paralleled, perhaps suggested by, a comparable students' Chemical Society in Edinburgh, 1784-5, clearly formed for discussion of the new French chemistry. Whatever the chemical preoccupations of the Glasgow students, the society brought together two young men who would continue their association momentarily, as original, founding partners of Tennant and Co., begetters of St. Rollox, namely Charles Macintosh and the above-mentioned William Couper.<sup>25</sup> This noteworthy group also contained, as well as Couper, two more sometime professors of chemistry, Adair Crawford of the Woolwich Military Academy, and John McLean, professor at the College of New Jersey (later Princeton University); also Alexander Tilloch, publisher of *The Philosophical Magazine*, John Finlay, a close chemical correspondent of Macintosh, and John Wilson of Hurlet, where he and Macintosh would initiate Scotland's first alum works. Macintosh contributed papers on dyeing, alum crystallization and alcohol, this last exhibiting familiarity with Lavoisian chemistry.<sup>26</sup>

The Chemical Society certainly offered opportunity for young chemists to pursue their particular, practical chemical interests, as exemplified by Macintosh, but at least as important for the future of manufacturing chemistry were the emergent associative bonds which it fostered. From this associational point of view, two further institutional venues have relevance. The Glasgow Chamber of Commerce, the first of its kind in Britain, was started in 1783, immediately in the wake of the peace ending the American War of Independence. This latter event saw the writing on the wall for Glasgow's chief existing driver of commercial prosperity, namely the import-entrepôt trade in colonial American tobacco, a market largely dominated in both Britain and Europe by Glasgow's mercantile élite, the 'Tobacco Lords'. These colonial traders also exerted powerful influence in local financial terms, able to invest in Scotland's nascent textile and iron manufactures and their ancillaries such as dyeing. The 1780's thus marks something of a shift of commercial focus, away from colonial trade monopolization and toward domestic manufacture. This shift is noticeable in the Chamber of Commerce's early focus upon improving the quality of manufactures, and influencing government on tax and tariff. Its other early preoccupations, halting smuggling, and the East India Co. monopoly, probably reflected the strong residue of colonial trade presence in the Chamber's membership. Charles Macintosh became a member, and his father, George, was an early president of the institution. Thus, when Macintosh joined the founding partnership of St. Rollox, it meant that Tennant, who tends to be regarded as senior partner (he took over financial control early on), was forging a relationship with the pre-eminent chemical manufacturers of Glasgow, the Macintosh family. Part of the reason for the siting of St. Rollox at the Monkland Canal was very probably this relation. The Macintoshes, at the apex of Glasgow commerce in the Chamber, had known the area well for decades. Their cudbear works and office were within close walking distance of the canal. One might begin to think therefore, that Tennant joined the Macintoshes, rather than the reverse; in the *Memoir* of his father, George jnr. mentions that Macintosh and Tennant were, 'for several years previous', business partners by the time of *both* St. Rollox bleaching patents (that is, previous to 1797).<sup>27</sup> The thought is reinforced by consideration of the fact that two of Charles Macintosh's business associates in the Hurlet alum works, John Wilson and James Knox, were also partners in Tennant and Co. The Hurlet alum works appears to have been virtually contemporary with St. Rollox, and in associational business terms, the firms had overlapping partnerships. This circumstance, and its timing, serves to emphasize the way in which, by the second half of the 1790's, this forceful grouping of chemically-inflected manufacturers had attained the chemical and commercial confidence to undertake not a single but a double initiative with reference to the foundation of major new enterprises.

By the mid-1780's there also existed the Commercial Society of Glasgow, 'one object of which was the discussion of subjects of a philosophical, and in some measure, of a political nature'.<sup>28</sup>

Charles became an active member, either of this Society or some comparable group, judging from the topics which his other essays addressed: political union with Ireland, balance of power, commercial treaties, agriculture, woollen manufacture, the Scottish iron trade.<sup>29</sup> In the 1780's and 1790's then, Glasgow clearly exhibited a set of educational and collective commercial institutions, voluntarist in nature other than the University. From our viewpoint, these institutions did not simply teach and promote chemical science and its manufacturing uses and potentials. They also functioned by generating and sustaining a chemico-commercial culture, visible nodes of association for commercially-oriented chemists whose ties of friendship, family and manufacturing business would provide social cohesion to the development of Glasgow's chemical manufactures in the coming decades.

## 2.ii Chemical Entrepreneurship

### *The Staple Highway: Charles Tennant*

The narrative of St. Rollox' origin, foundation, spectacular growth and commercial success, whilst acknowledging the significance of Charles Macintosh, tends to be understandably dominated, in terms of human agency, by the figure of Charles Tennant, a compelling story of transformation of a young rural silk weaver into the industrial Colossus of St. Rollox, an epic socio-economic trajectory of the industrial revolution. Tennant, first an apprentice then a silk weaver, worked in this highly-skilled occupation in Ayrshire when young. Aware perhaps of the increasing demand for textile bleaching, from long-established linen and recently growing cotton textile production, he switched occupation to bleaching, and ran a rural bleachfield in Darnley, Ayrshire, from 1788 (see Illustr. 5, p. 22). There, hearing of Berthollet's chlorine technique, most likely *via* James Watt or Watt's father-in-law the bleacher John McGrigor, both of whom were working on improvements to the Berthollet technique, Tennant commenced, after some experimentation, using the Berthollet potash-chlorine liquor with success, eventually modifying it by substituting lime for the potash. His immediate neighbour at Darnley was William Wilson, whose daughter Tennant would later marry in 1795. Wilson, a merchant and factor to the Earl of Glasgow, also had a son, name of John, whom we have already met, a fellow member of the University Chemical Society with Charles Macintosh, and a business associate of Macintosh in the nearby Hurler Alum Works, sited on land owned by the Earl. Three years later, shortly after the foundation of Tennant and Co., the firm took out a patent for the chlorine liquor (eventually lost in an informative court case of 1802), but further experimentation, using slaked lime and chlorine gas, produced the solid bleaching powder which replaced the liquor, and provided the chemical basis of St. Rollox' early ascent, and some financial basis for its expansion. The local communicative networks of family, friends, Chemical Society and business association were clearly instrumental in forming the genesis of St. Rollox and its new bleaching chemistry.

Thus far we have Tennant as the alert, opportunistic, young entrepreneur, moving occupation riskily from a skilled to a less skilled occupation with more expansive potential, willing to pursue new processes, recognising talented expertise when he met it, and incorporating it by business association into ambitious commercial novelty. This does not, however, suffice as a characterization of the way he developed St. Rollox. First of all, chemically considered, St. Rollox, after the new bleaching powder, may be considered as conservative. What it did was concentrate on already long existent, basic staples and processes, such as soap and sulphuric acid, rather than new products. When the Leblanc soda process was adopted in the 1820's, it was new in Glaswegian and Scottish terms, but it was by no means the first artificial soda, and all the pre-installation start-up costs, experimental research, up-scaling, equipment design, were absent, for by then it was a known and

tried process of chemical production, with a waiting market, relatively riskless. Similarly, the lead chamber process for sulphuric acid had been practiced in Scotland since 1749, at John Roebuck's Prestonpans manufacture. Tennant's concentration was not on radically innovative technique, other than the bleaching powder, but on using the St. Rollox site as a space for radically increasing the quantities of the common, basic chemical materials and products which it produced. The language of 'growth', 'expansion' and 'innovation' tends to obscure this conservative, and fundamental, feature of St. Rollox chemical production.

There are other notable features of Tennant's entrepreneurial practice. One striking feature in addition to the distributed network of sales agents, is his concentration on packaging, transport and product distribution. The initial site choice, by the Monkland Canal to ensure quick, easy transport of coal to the site, indicates sensible attention to such issues, but part of the reason the Glasgow-Garnkirk railway was an early arrival in Scottish rail development terms was Tennant's early realization of railway's advantages. He befriended George Stephenson, and worked to ensure the Caledonian Railway spur to Garnkirk. The mercantile fleet also displayed his close attention to transport, now in national and international import-export terms. For transportable packaging, St. Rollox remained with barrels, but installed an on-site cooperage for assemblage of pre-fabricated barrel components. In all these forms of development, Tennant's entrepreneurial style exhibited the impulse to own and control as many facets of the commerce as possible. In addition to production of relatively riskless chemical staples, the on-site packaging, immediate rail and water access, and the sea-going fleet bespoke a quest for, and ability to achieve, not simply maximal control and the co-ordination advantages derived therefrom, but as much independence as possible, relative freedom from reliance upon other packagers, distributors and transporters.

Externally to the company, Tennant also paid close and effective attention to politics. In the general political terms of the time he was termed a 'Radical', accurately enough if by that is understood classic bourgeois radicalism of the Reform period. It was an active radicalism, the reforming Crow Club at times meeting at St. Rollox. It was a radicalism that also associated him with men of comparable occupation, a type, an increasingly visible and powerful middle-class fraction who would be enfranchised by the 1832 Reform Act. He also acted politically for the advance of St. Rollox with the Leblanc process, pushing for abolition of salt importation duty, and opposing one chemical vested interest, which wished to prevent the advent of artificial soda. This interest was the Kelpers, numerous on the Scottish islands and west coast, the gatherers and burners of seaweed, or at least the proprietors and managers of estates where such work occurred. They produced much of the potash used in Britain, a strategically significant group in terms of chemical manufacture. This was the underlying conflict. It was about whether or not artificial soda, which needed mineral salt, would chemically supplant the established, vegetable-derived potash, rather than simply about free trade and Treasury receipts on salt, and Tennant and St. Rollox emerged a winner in the conflict.<sup>30</sup>

### *Secret Works and Serial Invention: Charles Macintosh*

If Tennant's entrepreneurship after bleaching powder can be described as chemically conservative, staple-focused quantitative expansion, complemented by strategic political action where necessary, and by in-house development and control of as many commercial factors as possible, then consideration of Charles Macintosh's complex and varied career, marked by serial manufacturing initiatives, multiple business associations and chemical invention, offers a striking contrast in entrepreneurial character. The relevant background pre-dates his birth in 1766, for the Macintosh family were already chemical manufacturers. His father George had been involved in tanning and shoe-making, and in the 1770's, with the financial aid provided by the Glasgow tobacco trader

John Glassford, took over an established and patented, though currently failing, dye making business, starting manufacture at Dunchatton in east Glasgow (see Illustr. 4, p. 22, map, southeast quadrant, for location of Dunchatton and the manufacturing premises). Macintosh Snr., 'who is a great hunter after secrets',<sup>31</sup> employed the previous owners of the process as managers. The dye, named cudbear, was lichen-derived, and chemically capable of manipulation of colour gradations through pink and red to blue and purple, and the Macintosh manufacture proved successful and long-lived. At its inception and for decades after it possessed two very striking features. It was surrounded by high walls, to hide the production processes from the curious eyes of 'intelligencers' or spies. In this its protective design followed that of Roebuck's lead vat acid process at Prestonpans. Even more striking was the work force, composed of Highlanders who were largely monoglot Gaelic speakers. The Macintosh family came from the northern county of Ross-shire, and they knew that Scots Highlanders were already familiar with the process, at least in undeveloped terms, because they used lichen to make their own textile dyes. The work force was essentially internally imported, semi-skilled labour, and the workers numerous. They were moreover sworn to secrecy, attended a nightly roll-call, and were housed on-site, inside the walls. Many rarely left the compound, nor learnt any English.<sup>32</sup> George Macintosh had erected a quadruple security barrier, of oath, roll-call, wall and language, to protect the details and practice of the cudbear process, and the security would seem to have worked insofar as no other cudbear manufacture appeared in Glasgow.<sup>33</sup> Dunchatton was thus a remarkable socio-historical enclave, a site of production whose fuller comprehension requires appreciation of internal migration from the *Gaidhealtachd*,<sup>34</sup> industrial urbanization of such populations, and the persistence of local Gaelic cultures in such circumstances.<sup>35</sup> This place, of chemical enclosure and jealously guarded secrecy, was where Charles lived from childhood, the Macintosh house being on site and also functioning as the company office.

Charles at a still youthful age, as well as attending the chemistry class at Glasgow University (and Joseph Black's in Edinburgh, also later Thomson's in Glasgow), participated in the family business, travelling on at least two occasions, to Germany, Holland and France (including Rouen), on sales business for the company, and also for the Prestonpans acid works, now taken over by John Glassford. He probably also pursued chemical intelligence, experimenting on French plants for dye potential, and noting Holland's sugar of lead manufacture and its successful export business to Britain.<sup>36</sup> He started his own entrepreneurial career before he was twenty, a sal ammoniac plant comparable to James Hutton's in Edinburgh, based on the Baumé soot-bed process. This commenced an entrepreneurial career of a large number of chemical manufacture initiatives, by no means all successful, but some of which brought him further prosperity, scientific reputation (F.R.S 1823), and eponymous commercial renown (the 'Mackintosh' [*sic*], a waterproof coat). He commenced sugar of lead manufacture in 1786, apparently lowering costs enough to export to Rotterdam, successfully undercutting prices of the dominant Dutch sugar of lead manufacture which had so impressed him on his continental tour. He and his father learnt of efforts in trials of the new chemical bleaching, and in 1788 Charles was 'making experiments at home in order to find out the secret', then travelling to Manchester to learn more.<sup>37</sup> He had also launched mineral acetate production, substituting lime for alumina, a British novelty, and of use particularly in calico printing. He would start the Hurler Alum works with John Wilson, and initiated a further alum site north east of Glasgow in the Campsie hills. The production of the chlorine bleaching powder for the new Tennant Co. in 1798, again highly novel in its gas-to-solid (chlorine-to-slaked lime) reaction, occasionally ascribed to Tennant, was the foundational experimental work of Macintosh.

The torrent of manufacturing processes did not cease with the establishment of St. Rollox, where he remained as a partner until 1814. He suggested a substitute for copper sheathing for

vessels to the East India Co. Also for that company he produced a fused saltpetre process with considerable weight and space saving for stowage capacity for sea transport from India, the process demonstrated to the Directors' satisfaction, but not adopted. On the dyeing front, in addition to continuing the Cudbear Works, and the Turkey Red dyeworks started by his father in 1787 with the aid of Papillon's expertise in the 'secret'<sup>38</sup>, he established a Prussian Blue process, and prussiate of potash for calico printing. Prospecting at the Glasgow Gas Works he found naphtha (a coal tar derivative), a waste or by-product of the coal-gas production. Either detecting its India rubber-dissolving property himself, or more likely knowing of James Syme's discovery of it in Edinburgh in 1818, he formulated the production of waterproofed cotton by using sheets of rubberized naphtha sandwiched between layers of cotton, an eventually successful manufacture which he relocated to Manchester. His last significant cooperative venture was with James Nielson, an eventually successful patenting, in 1828, for Nielson's hot-blast furnace metal-smelting process. His initial acquaintance with Nielson was probably a result of his prospecting of the coal tar by-products at the Glasgow Gas Works, where Nielson was a foreman. Prior to that, he had produced a new preparation of iodine, further innovations in textile treatment for calico printing, started a yeast factory in London (eventually failing), and patented an iron-steel conversion process with carburetted hydrogen.

Considered from an entrepreneurial viewpoint, the failures are instructive with reference to the politics of commerce involved. The yeast factory failed because of opposition from the London Porter Brewers. The East India fused saltpetre was refused adoption precisely because it worked. It benefited especially from Macintosh's detailed attention to the problems of bulk, stowage and hazard attending nitre transport. The company finally declined it, despite its apparent rationality, because it diminished the tonnage by which their 'patronage' was paid. The fused nitre, eliminating water of crystallization and impurities, thereby diminishing tonnage and volume, was in fact the opposite of what was wanted, because of the specific government-related payment regime. Clearly these matters, such as local powerful opposition to intrusive yeast production, required entrepreneurial attention as meticulous as the strictly chemical attention Macintosh devoted to the experimental work validating the processes he promoted. The point can be expressed more generally. The rationality of chemical manufacture was not necessarily or automatically congruent with localised rationalities of existing commercial practice. Macintosh's failures were not owing to defective or inefficient chemistry, but to inadequate apprehension of these locally specific commercial conditions. Both cases are from London, a commercial environment far less known to him than that of Glasgow, and more complex.

Macintosh is perhaps unusually informative in considering entrepreneurship, because of a relatively complete record of failures and successes. Overall, his activity differs substantially from that of Charles Tennant. Although far less single-minded and considerably more diversified than Tennant, his operations nonetheless possessed an identifiable internal coherence, for instance in the number of projects focused upon textile treatment and dyeing. The alum works and acetate process were relevant from this viewpoint, the potential application among others being their specific properties as mordants. He also used Glasgow Gas Works ammonia by-product in the Cudbear processes. We tend perhaps to over-individuate in our focus on sites, and this can misdescribe their functionality. Instead of individualized accounts of Macintosh's apparently diverse manufactures, an account which recognizes an interactive chain of enterprises, connecting alum, ammonia and acetate with cudbear, Turkey Red and thence outward to calico printing, is more realistic for appreciating the overall coherence of these aspects of Macintosh's entrepreneurship.

The coal tar derivative naphtha's properties as solvent were also pressed into immediate textile adaptation. In this sense, Macintosh was simply extending his family dye-stuff business into new



textile-related products. Further characteristics reinforce the contrast with Tennant. Macintosh was far more mobile, a well-travelled and well-educated practical chemist, and not solely Glasgow-sited. His multiple projects tended to remain of medium size, unlike the singular gigantism of St. Rollox, and a thread of persistent chemical novelty, chlorine powder, mineral acetates, dyes and mordants for calico printing, rubberized cotton, ran through them. Stated thus, the Macintosh chemical coverage of all the key preparative stages of textile production before actual dyeing becomes readily apparent.

Perhaps less noticeable, but just as indicative of his particular entrepreneurial character, was his habit of chemical prospecting and scavenging. His very first effort, in sal ammoniac manufacture, relied, like Hutton's, on the free waste product of soot. The alum works were firstly based on cast off schist from local coal mines. The naphtha was an unused gas production by-product, like the ammonia. The point of scavenging in this sense is not just the finding of new materials. The materials are available, unintentionally as it were, and in the first instance, as the result of the labour of others. First-phase production thus comes if not for free, at least for considerably reduced cost. Nowadays we might understandably call him a chemical recycler, or re-purposer, but perhaps that does not quite capture the prospecting and scavenging habit quite spectacularly displayed by Macintosh. Rather, he was giving chemical purpose and commercial value to the purposeless and valueless cast-offs of others' labour. Mobile, prospective, scavenging, qualitatively diversifying rather than quantitatively accreting, this increasingly expert and chemically innovative entrepreneurial practice thus provides a thorough and instructive contrast with Tennant's and St. Rollox.

#### *Chemical Necromancy: Robert Townsend*

A third example of chemical entrepreneurship, that of Robert Townsend, serves to reinforce and extend such points of contrast. Townsend started the Port Dundas Chemical Works in the mid-1850's, less than a mile to the west of St. Rollox, at the Forth-Clyde canal basin (*not* on map section Illustr.4; consult full David Smith 1828 map at GUL website). It soon became a large enterprise, eventually building a chimney whose height exceeded even that of Tennant's stalk. J.D. Burn, overwhelmed by St. Rollox, was fascinated by Port Dundas and the mode of manufacture it exhibited, which differed substantially from what we have encountered in either the Tennant's or Macintosh works. It was 'one of the wonders of Glasgow', Burn remarked, 'The business carried on in this establishment is quite peculiar to itself, so far as Scotland is concerned....during the whole of our existence [we] never passed through such a valley of dry bones as we witnessed in this strange dissecting room.'<sup>39</sup> The premises were sizable, occupying 14,000 square yards, the main building upon an inclined plane, the high end by the canal basin for the reception of raw materials. Inside, it was filled with an assortment of apparatus 'that would puzzle any ordinary philosopher to understand.'<sup>40</sup> On the high platform was the dissecting hall, beneath it several vast boilers, each with thousands of gallons capacity. Elsewhere were two ranges of furnaces, one for calcining iron pyrites to free the sulphurous gas, thence conveyed by lead pipes to nine immense lead conversion chambers to produce sulphuric acid. Port Dundas had this in common with St. Rollox, both producing large amounts of sulphur for acid, most of which was then consumed on-site for further production processes.

There the comparison ends. St. Rollox was firmly mineral-based in its practical chemistry. Other than sulphur, Port Dundas by contrast used organic raw materials, namely animal carcasses. These were dismembered in the 'dissecting hall', then stripped and picked in a separate building. Machines crushed and ground the bones, which were then calcined to produce charcoal, in turn then sold to sugar refineries (for decolourization and de-ashing; two refineries were close by in

Glasgow according to Smith's map, and extensive sugar refining was beginning large-scale development down the Firth of Clyde at Greenock). The other animal remains were boiled and reduced, in order to make manure. From these animal materials the works also produced glue or 'size' for calico printers, grease for soap-makers, and ammonium sulphate. In terms of quantities, by the late 1850's Port Dundas was producing 150-200 tons of manure per week, selling for a price of £7-£9 per ton, 10-15 tons of charcoal per week, and used 70 tons of vitriol per week to drive its various processes. This last particularly caught Burn's attention. 'This extraordinary agent is used by Mr. Townsend in his chemical necromancy, by which means he transmutes useless substances into valuable articles of commerce.'<sup>41</sup> It appears then that Port Dundas was supplying an entirely different market from St. Rollox, its charcoal going to refineries, and the manure back to the agricultural countryside from which its raw materials originally derived. Townsend thus has some manufacturing kinship with Macintosh, each able, with chemical manufacturing capacity, to derive additional value from relatively unvalued cast-offs. Townsend however, unlike Macintosh, may be described as an authentic materials recycler, whether such was his conscious intention or not. The original animal produce of the country was transmuted chemically in the town, and returned to the country--- a cycle which Adam Smith, among others, had analysed in abstracted structural fashion, rather than Burn's materially precise terms.<sup>42</sup>

These three chemical entrepreneurs were indubitably successful in chemico-economic terms, but the routes to success, the staple chemical highway of St. Rollox, the longer, twisting trail of multiple chemical and manufacturing initiatives followed by Macintosh, and the country-to-town-to-country recycling of Townsend, show that in this period, no singular entrepreneurial mode, nor even a set of comparable modes, was definitive of chemical manufacturing success. Nor are these entrepreneurs straightforwardly assimilated by current modelling of industrial revolution owner-industrialists and of entrepreneurship, although a degree of comparative light is undoubtedly thrown upon them by recent work.<sup>43</sup> They may, for instance, be described as 'middle-class' in origin (Tennant specifically 'lower-middle'), and Tennant and Macintosh had extensive prior experience in the manufactures they industrialised. However, unlike some other significant industrial-scale works owners, Tennant did not undertake sector diversification that we know of into forms of finance, nor into non-chemicals within the manufacturing sector, nor enterprise outside manufacturing other than his in-house mercantile shipping, which was in any case shipping primarily for St. Rollox, not a general trading organization.<sup>44</sup> As for Macintosh, it may be ironically questionable, according to the size criterion, whether he qualifies as an 'industrialist' at all, in that, with the exception of St. Rollox, his particular owned and managed operations tended to remain small to medium in scale. Yet such a judgement would in turn obscure the sense of the coherent functional interaction of the textile-directed chain of the various operations, a mode of entrepreneurship not easily recognizable in the available models. In his St. Rollox phase, as partner-owner of a large-scale enterprise, and also with reference particularly to the range of his inventive capacity, his technical expertise and his scientific cultivation, he is comparable perhaps especially with fellow-Scot James Watt, perhaps also with James Keir in the Midlands, and Thomas Henry in Manchester. The work of Peter Jones has rendered this a type more categorically recognisable than hitherto, the distinctive '*Savant-Fabricant*' figures of early industrialization, men who successfully combined scientific knowledge, technical expertise and manufacturing experience.<sup>45</sup> Townsend is even more difficult to categorize, at one level initiating profitable industrial scale-transformation for charcoal and manure, yet doing so in strategic ways which recall pre-industrial material 'oeconomies' of town-country circulatory exchange.<sup>46</sup> Any innovation attributable to him thus has a complex historical form. In terms of scale he industrialized, yet this industrialization was itself a renewal, revivifying in industrial terms an older commercial form of rural-urban cyclicality.

Mokyr's essay on entrepreneurs in the industrial revolution continues his strategic interpretive stress upon institutional and cultural factors.<sup>47</sup> He emphasizes the slow evolution of Parliament away from 'rent-seeking' assumptions and toward liberal market orientations; the behavioural normativity of gentlemanly politeness and trust, the latter particularly significant with respect to contract and credit; trade associations and informational networks; and the strategic importance of choice of partners in new industrial ventures. This latter point is dramatically endorsed by the St. Rollox partnership of Tennant and Macintosh. With respect to trust, however, one might instance its spectacular failure in the case of Tennant's substantial help and instruction in the new method to Irish bleachers, from whom he received little or no payment.<sup>48</sup> This is not to negate Mokyr's gentlemanly trust perspective, merely to insist upon its demonstrable limits, its less than universal nature, particularly where geographically and culturally extended commercial relations were in play. With respect to local Glasgow commercial culture, we might add two sorts of relevant institution not covered by Mokyr, the new formal and quickly chartered collective institution, the Chamber of Commerce, with its focus on manufacture; and, of genetic significance, the University, not simply for its chemical teaching, nor yet for any commitment to techno-scientific public communication, but for the voluntarist association of the Chemical Society, and the combination of chemical enthusiasms, personal and commercial associations at whose origins it lay. Overall then, we may at least start to think of Glaswegian chemical entrepreneurship as partially intelligible within some recent analytical and interpretive perspectives of economic history, but at the same time, as having substantial additional and different features to add to and qualify such historical understandings.

### 3. Conclusion

By way of conclusion, rather than summarising results so far, it may instead be worth reflecting on the broader issue of the nature of the historical developments involved, as premised in discontinuous conceptions of chemical and industrial revolutionary change, and as gesturally represented in 'Chemical Behemoth', pp. 9-10. There is no doubt that the expanding St. Rollox site represented a visibly dramatic step-change, both for chemical manufacture generally, and for bleaching powder, then acid and soda production specifically. Its rapid rise in the first quarter of the nineteenth century renders it an exemplary, if chronologically late candidate for 'take-off' industrial historiography. There is equally no doubt that the chemical knowledge of Charles Macintosh was up-to-date, informed by the new chemistry of Lavoisier and his French colleagues, and that the new chemical technique of St. Rollox is immediately and directly relatable to a key component of revolutionary chemistry, namely the multiplication of gas discovery, the properties and compositional implications thence investigated, and the provocation all this provided for a systematic reformulation of the science, together with its practical methods of analytical and synthetic procedure. Macintosh's immediate chemical circle had an at least informal consciousness of this. One friend, in the midst of a correspondence discussing in detail the experimental problems arising in the early sal ammoniac manufacture, wrote, in 1786, four years before the English translation of Lavoisier's *Traité Élémentaire*, 'From the perusal of Fourcroy's chemistry, I have become a perfect convert to the aerial system, although I think most of the disputes on this subject, and the doctrine of phlogiston, are mere playing on words'.<sup>49</sup> This evidenced the chemical attitudes of the young practical chemists, keenly interested in the very latest chemistry, their focus particularly on the systemic role of gas components, the 'aerial system', but not overly distracted by the semantics of intractable theoretical dispute. To this not inconsiderable extent, the changes in question, chemical, technical and economically productive, do not have to be violently shoe-horned into a narrative stressing intensive, discontinuous change.

Yet there are other detailed features of change which complicate any straightforwardly discontinuous emphasis. Remaining for the moment with the chemical dimension of manufacture, the key role of chlorine, understandably emphasized, needs a fundamentally qualifying addition. In fact, the first Tennant & Co. patent, as already mentioned, lost the court case of 1802. This was the bleaching liquor patent, and it lost because it also specified lime in suspension, which Tennant had used to replace Berthollet's potash additive, and lime was already in comparable bleaching use, a point sufficient in the legal specifications of the time to invalidate the patent. The second St. Rollox patent was for the dry bleaching powder process, chlorine-based but crucially dependent on the reaction with slaked lime to produce not liquor but powder, the great commercial advantage of St. Rollox, and the fundamental contribution of Macintosh. Whence and why the lime?

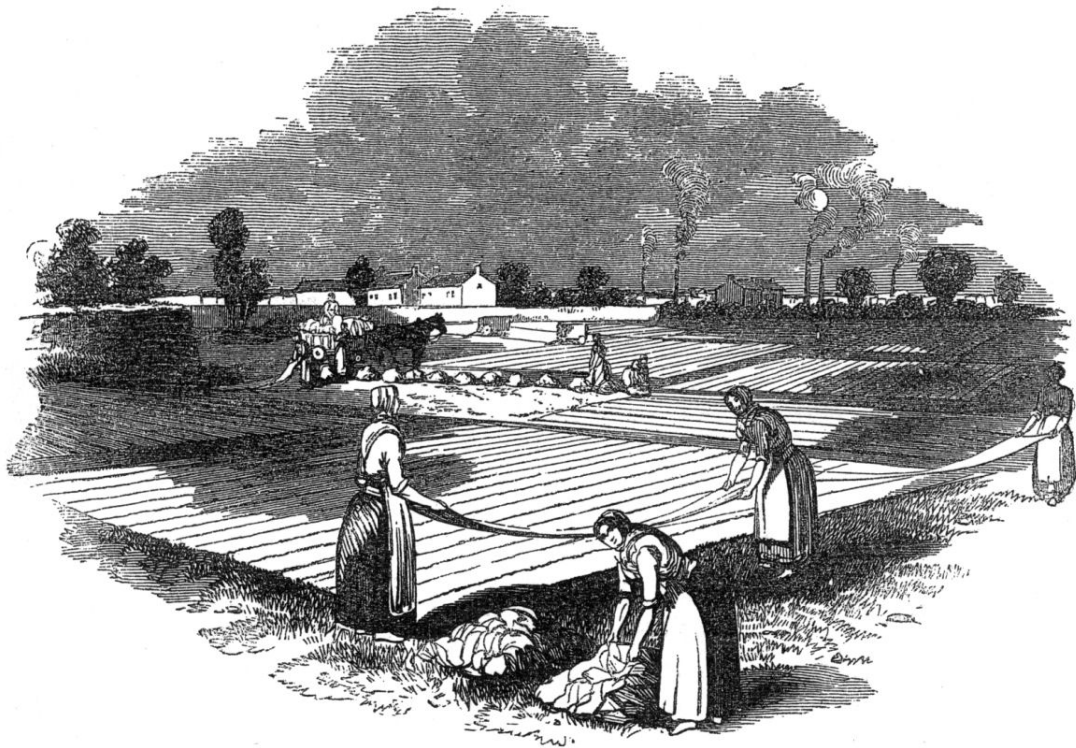
Since 1750, bleaching had chemically modernised with sulphuric acid, produced in quantity by Roebuck's works, and considerably shortening bleaching time. In the 1760's Edinburgh's academic chemists Joseph Black and Francis Home, had argued chemically for the introduction of legally banned lime, convinced of its relevant property, under appropriately focused quantitative management. Tennant and Macintosh were also lime enthusiasts in this genealogy of Scottish bleaching technique, Macintosh in particular highly likely to have known of the work of Black and Home.<sup>50</sup> From this viewpoint, first Tennant, then Macintosh, might be considered not as adding lime to chlorine, but adding French chlorine to chemically established Scottish lime. If that may be thought of as tendentiously overstating the case, then consider also Macintosh's statement to a correspondent: 'Lime has long been a favourite nostrum of mine, having first used it many years ago'.<sup>51</sup> He used it with reference to sal ammoniac, alum and elsewhere, and had thorough familiarity with its properties in its mild, caustic, liquid and slaked states. It was his familiar chemical standby, a first port of reactive chemical call. It was thus utterly unsurprising that he should investigate its potentials in chlorine combinations. Lime, so to speak, does the business, in its itinerary through sal ammoniac, acetate, alum and chlorine processes of production. In this sense, Macintosh was not simply a 'modern' chemist, but an educated and knowledgeable inheritor of the previous generation of pre-revolutionary chemists' practical and theoretical knowledge. Chemically, therefore, we require an equal stress upon pre-revolutionary chemistry to understand historically the genealogy of St. Rollox bleaching. That in turn induces an authentically continuous dimension to the chemical history of St. Rollox.

We might also think of a direct comparison of the Macintosh Cudbear Works with St. Rollox in its first years: St. Rollox employed fewer workers, plausibly successful in production terms, but whose product was initially limited enough to be transported down to Glasgow in wheel barrows. The Cudbear Works was a larger, successfully established business.<sup>52</sup> If we stand in 1800, what does that mean? Did Tennant and Macintosh intend and project their Behemoth, or was it conceived in more moderate terms, as a likely profitable initiative on the current scales of chemical production? We cannot hope for definitive answers with respect to such questions of intentionality and projection, but they are worth posing if only to emphasize the likelihood of relative nescience of the future in 1800. It is a profound error to retroject the Behemoth scale of what St. Rollox became back to its ordinary intentionality. It became what it became, but that was not clearly knowable or predictable in 1800, when ambitions were entirely likely to have been more limited. Further, as the case of Port Dundas indicates, it may also be equally misguided to think of all the features of the material 'oeconomies' of pre-industrial northern Europe and Britain as being simply obliterated by Britain's industrialization processes. Port Dundas was not started until the 1850's, the most recent of the manufactures examined here, yet perceived as it were archaeologically, it contained a recognisable pre-modern rural-urban recycling stratum in the commercial form of its operation.

Distinctive features of the Cudbear Works also bear more extended examination for their presence elsewhere. Its early modern, pre-industrial retentive secrecy, reminiscent of Prestonpans, was not Macintosh's only secretive process. Another of his works, the alum works at Campsie established in 1797, conveniently near both to alum schist and to the new Lindsay calico printing works, was also known as the 'secret works', as, in imitation of cudbear manufacture in Glasgow, Macintosh attempted to sequester the details of his alum process. The Turkey Red Works were also guarded by high walls, and it is also worth remarking that despite the St. Rollox bleaching process, Macintosh thought it worth retaining a large bleachfield in Glasgow. This surviving ethos of pre-industrial manufacture can be contrasted with Tennant's far more communicative attitude, for example his willingness to instruct, for an appropriate fee, the Irish bleachers. Macintosh worked for a time with Lancashire bleachers, but retained an attitude of guarded secrecy toward aspects of development of the Berthollet process, as indeed did James Watt, both men unwilling to forego any competitive edge which withheld chemical knowledge might provide.<sup>53</sup>

The partners' practices, both convergent and divergent at particular moments, illustrate the ways in which pre-industrial behavioural reflexes could and did persist, contemporary with the supposed liberal openness of a knowledge-based industrial economy, or perhaps more precisely, the way in which a publicly communicative ethos of accessible exchange of scientific and technical knowledge had a differential uptake with respect to manufacturing commercial practice, even as between close entrepreneurial partners. Townsend's Port Dundas enterprise, innovative in industrial scale, was not chemically innovative in its basic practical chemistry, nor its urban-rural recycling form of commerce.

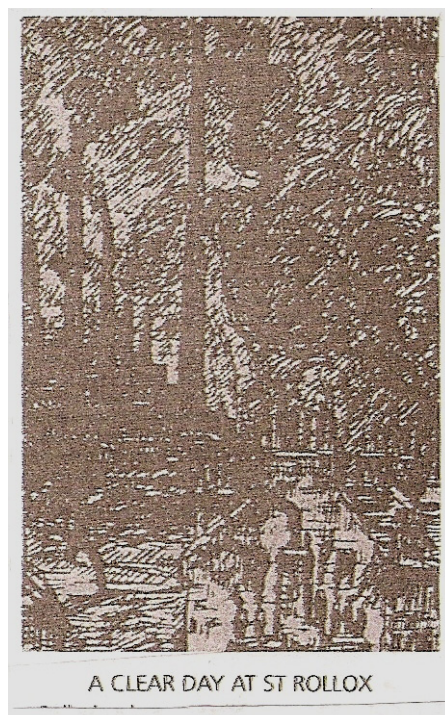
These kinds of concluding examples, emphasizing the persistence of various kinds of pre-revolutionary commercial forms and behaviour, and of chemical knowledge and practice, coeval nonetheless with consciousness of fundamental change in chemical science and with comparably fundamental economic development, reinforce the need for a more nuanced semantics of change. This would not necessarily attempt simply to refute any discontinuities inherent in revolutionary change by counter-posing evidence and argument for an opposite case: we are long familiar with the perdurability of pre-industrial economic occupation and organization into the age of industry, and it is surely futile to think that either case simply refutes the other. The problem cuts more deeply, and its fundamental form is narratological as much as it is interpretive. It is that both cases, at given points in time, are coevally true, but that we find it difficult to institute the terms of a historiography which coherently relates the range of contemporary historical phenomena evidentially apparent. The interpretations, of radical change or of slow and partial growth and pre-industrial persistence, seem to pull in opposed narrational directions. To this dilemma, the current essay has added, I fear, further comparable difficulty. It has stressed the presence of a revolutionary science of chemistry, nonetheless containing within its practices obvious and significant pre-revolutionary features. It has further pointed to an unresolved dialectic of contemporary entrepreneurial dispositions and practices, of knowledge and communication, publicity and secrecy, stressed across a related variety of scientific, manufacturing and commercial life. Such dialectics, we may concludingly suggest, have been persistently present throughout both early modern and modern times, but with very variable historical visibility. One advantage to studying a period covering pre-industrial to first and second phase industrialization is the relative visibility and location of the dialectically stressed elements, rendered more readily apparent in an age of rapid and fundamental change. To historians it still remains, however, to work out, informatively and coherently, just how to integrate such coevals when they feature as evidentially contradictory elements within opposing narrative formations of the 'two revolutions'.



Illustr. 1: Vale of Leven Bleachfield, C18th.



Illustr. 2: Engraving, David Octavius Hill, *The Opening of the Glasgow Garnkirk Railway 1831*. St. Rollox Works in the background.



Illustr. 3: C19th. satirical print, St. Rollox.



Illustr. 4: Section of David Smith, *Plan of the City of Glasgow and its Environs*, 1828.



Illustr. 5: Darnley Bleachfield.



## (Endnotes)

- 1 Peter Morris, Colin Russell and John Smith (eds.), *Archives of the British Chemical Industry, 1750-1914: A Handlist* (Oxford, British Society for History of Science, 1988), lists no locations for St. Rollox company archives. I have located one, the letter book for 1801-3, early in the company's history, useful primarily for early business organization and development. The Mitchell Library Glasgow holds some site development plans from 1830 to 1900 (ref.TD146), and smoke emission legal depositions (ref. T-MJ409). The letterbook somehow survived through the Tennant Co.'s absorption by ICI, and ICI's Zeneca Group amalgamation with AstraAB to form AstraZeneca PLC.
- 2 Duncan Macfarlane and George Cleland, *New Statistical Account of Scotland*, (vol. 6, 'Lanark', 1845).
- 3 See Hasok Chang and Catherine Jackson (eds.), *An Element of Controversy: The Life of Chlorine in Science, Medicine, Technology and War*, (British Society for the History of Science, 2007), ch. 5, by Manchi Chung, Saber Farooqi, Jacob Soper and Olympia Brown, for chlorine bleaching in this period, and for St. Rollox in particular, pp. 168-174. First published nearly fifty years ago, Alfred Musson and Eric Robinson, *Science and Technology in the Industrial Revolution*, (Manchester University Press, 1969), chs. vii-x, remains the most informatively detailed treatment of British chemical technology and manufacture during the period.
- 4 See this volume, 'Production' Section Introduction, ...
- 5 For recent work on entrepreneurship in this period, see François Crouzet, *The First Industrialists: the Problem of Origins* (Cambridge University Press, 1985), and Joel Mokyr, 'Entrepreneurialism in the Industrial Revolution', David Landes, Joel Mokyr and William Baumol eds., *The Invention of Enterprise* (Princeton University Press, 2012), 183-210.
- 6 John Tennant, Charles's son, recorded employing 887 men, but in addition, 807 boys. See Simon blow, *Broken Blood: The Rise and Fall of the Tennant Family*, (London, Faber and Faber, 1987), 65.
- 7 Some figures are given in Musson and Robinson, *Science and Technology*, 327 (see note 4). Musson and Robinson do not however give cost per ton, estimated to decrease five-fold in the first twenty-five years of production.
- 8 See Jan Lucassen, 'Working at the Ichapur Gunpowder Factory in the 1790's', Pts. I & II, *Indian Historical Review*, 39 (2012), 19-56, 251-71. With thanks to Andreas Weber for bringing this work to my attention.
- 9 John Burn, *Commercial Enterprise and Social Progress: or, Gleanings in London, Sheffield, Glasgow and Dublin*, (London, Piper, Stephenson & Spence, 1858), 118.
- 10 Burn, *Commerce and Enterprise*, 114-19.
- 11 George Dodd, Charles Knight, James Thorne, Harriet Martineau, William Harvey and William Wylie, *The Land We Live In: a pictorial, historical and literary sketch-book of the British Islands*, (vol. III, Scotland, Ireland and the Devonshire Coast, London, William Orr and Co., 1846), 213.
- 12 Burn, *Commerce and Enterprise*, 115 (see note 9).
- 13 Walter Scott, *The Antiquary*, original publication 1816, edition referenced is *The Antiquary*, (vol.1, New York, Van Winkle and Wiley, 1816), ch.15, 154, 160.
- 14 *The Antiquary's* representation of Tennant and Co. may in fact be anachronistic. The novel is set

in the 1790's, so at that time Tennant's had existed for at most four years. It is plausible, just, that by 1800 Tennant's sales agent network and general commercial eminence were such as to frame the scene set by Scott, but it is perhaps more likely that Scott's depiction reflects a state of affairs around the time of writing, 1815-16.

- 15 Text available at the Royston Road Project, [www.roystonroadproject.org](http://www.roystonroadproject.org), section 'Garngad & Royston'. For music, listen to Ron Angel or Big Big Sea, 'The Chemical Worker's Song', both available on YouTube. This is a C20th. song, also known as 'The Process Worker's Song', sometimes 'The ICI Song', and features life expectancy, caustic burn, gypsum and cyanide.
- 16 Simon Blow, *Broken Blood*, 59 (see note 6).
- 17 Neil Coley, ch. 4 'The Alkali Industry', in Colin A. Russell ed., *Chemistry, Society and Environment* (The Royal Society of Chemistry, Cambridge, 2000), p. 82.
- 18 'Glasgow Sketches' (1889), a compilation of nineteenth century excerpts from local newspapers, Mitchell Library (Glasgow Room), ref. G330.193.01444 MIL.
- 19 See the record of 'St. Rollox Emission Depositions' (1822), Mitchell Library, Glasgow.
- 20 Musson and Robinson, *Science and Technology*, (see note 4).
- 21 David Smith, *Plan of the City of Glasgow and its Environs*, (Glasgow, 1828). For the whole map, with zoom facility, legibility, and close inspection navigation, see Glasgow University Library site for maps:  
[www.gla.ac.uk/services/library/collections/virtualdisplays/mapsofglasgowhistoricaltodigitalofglasgowhistoricaltodigital/davidsmith1828planofthecityofglasgowanditsenvirons/](http://www.gla.ac.uk/services/library/collections/virtualdisplays/mapsofglasgowhistoricaltodigitalofglasgowhistoricaltodigital/davidsmith1828planofthecityofglasgowanditsenvirons/)
- 22 Roger Emerson and Paul Wood, 'Science and Enlightenment in Glasgow, 1690-1802', Charles Withers and Paul Wood eds., *Science and Medicine in the Scottish Enlightenment*, (Tuckwell Press, East Linton, 2002), 97-99.
- 23 William Irvine, *Essays, Chiefly on Chemical Subjects* (J. Mawman, 1805), 475-90.
- 24 For Thomson, see J. B. Morrell, 'Thomas Thomson: Professor of Chemistry and University Reformer', *British Journal for the History of Science*, 4 (1969), 245-286, and idem. 'The Chemist Breeders: the Research Schools of Liebig and Thomas Thomson', *Ambix*, 9 (1972), 1-46.
- 25 Emerson and Wood, 'Science and Enlightenment', 128-129 (see note 22); fn.63 contains brief information on this society. An earlier useful source is George Macintosh, *Biographical Memoir of the late Charles Macintosh*, (Glasgow, Blackie & Co., 1847), 6-8. The *Memoir* is additionally valuable in that much of it is composed of printed primary sources, particularly Macintosh's correspondence and writings. The Society was not simply a 'student' society: Adair Crawford had been taught by Irvine, and worked with him in the later 1770's, but by the late 1780's Crawford was by no stretch of imagination a 'student'.
- 26 Macintosh, *Biographical Memoir*, 6-8, (see note 25).
- 27 Macintosh, *Biographical Memoir*, 37 (see note 25).
- 28 Macintosh, *Biographical Memoir*, 9 (see note 25).
- 29 Macintosh, *Biographical Memoir*, 10-16 (see note 25). The papers written by Macintosh seem entirely suitable for the Commercial Society, but his son, George Jnr., while composing the *Biographical Memoir*, notes receiving unspecified information which may have indicated that Charles' essays were written for some comparable group. See *Memoir*, Editorial Note, 9.

- 30 Obituary of Charles Tennant, Institution of Civil Engineers Letter Books, 9 vols. 1839-49, vol. 1, Shelf Mark 624/629 (410)31G.
- 31 McGrigor to Watt, April, 1788, cited in Musson and Robinson, *Science and Technology*, 293.
- 32 George Stewart, *Curiosities of Glasgow Citizenship; as Exhibited Chiefly in the Business Career of its Old Commercial Aristocracy*, (Maclehose, Glasgow, 1881), 70.
- 33 Though see Stewart, *Curiosities*, 71, where Stewart records that one Highlander absconded to London, providing technical information to a company which set up cudbear production. The company did not however prosper, and closed within a few years.
- 34 The Gaelic speaking areas of Scotland.
- 35 For informative analysis of such processes, see Charles Withers, *Urban Highlanders: Highland-Lowland Migration and Urban Gaelic Culture, 1700-1900* (Tuckwell Press, East Linton, 1998).
- 36 This and following detail on Macintosh's chemical career are taken from Macintosh, *Biographical Memoir*, particularly the 'Introduction', xii-xix, and the additionally narrated accounts of Macintosh's activities throughout the main text.
- 37 Musson and Robinson, *Science and Technology*, 293-4.
- 38 Macintosh, *Biographical Memoir*, 22. George Macintosh Snr., writing to Charles, claimed to have thoroughly improved upon what they had from Papillon, improving colour and shortening dyeing time.
- 39 Burn, *Commerce and Enterprise*, 119 (see note 9).
- 40 Burn, *Commerce and Enterprise*, 119 (see note 9).
- 41 Burn, *Commerce and Enterprise*, 120 (see note 9).
- 42 Adam Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations* [1776], R.H. Campbell, A.S. Skinner and W.B. Todd, eds., ( Volumes 1-2, The Glasgow Edition of the Works and Correspondence of Adam Smith, Clarendon Press, Oxford, 1976), 1, 284
- 43 See François Crouzet's detailed and informative study, *The First Industrialists: the Problem of Origins*, (Cambridge University Press, 1985), and Mokyr. 'Entrepreneurship', (see note 4).
- 44 For such diversification see Crouzet, *First Industrialists*, 16-17 (see note 4).
- 45 Peter Jones, *Industrial Enlightenment: Science, Technology and Culture, in Birmingham and the West Midlands, 1760-1820*, (Manchester University Press, 2009), ch. 5.
- 46 See Joppe van Driel, 'Ashes to ashes: the stewardship of waste and economic cycles of agricultural and industrial improvement, 1750-1800', *History and Technology*, 30 (2014), 177-206.
- 47 J. Mokyr, 'Entrepreneurship' (see note 4).
- 48 For this episode, see Blow, *Broken Blood*, 34 (see note 6).
- 49 John Finlay to Charles Macintosh, February 1786, in Macintosh, *Biographical Memoir*, 19 (see note 25).
- 50 For fuller exposition of the chemistry of lime in bleaching at this time, see John R.R. Christie, 'Chemistry, Agriculture and the Rural Economy in Eighteenth century Scotland', 13-14 (forthcoming).

- 51 Macintosh to his Tennant business partner, James Knox, Glasgow, 20<sup>th</sup> January, 1800, in Macintosh, *Biographical Memoir*, 25 (see note 25).
- 52 The *New Statistical Account*, (see note 2) describes the Cudbear Works as a 'large scale' enterprise, though by this date it would be surpassed by St. Rollox.
- 53 For the introduction of Berthollet's process in Britain in general, Scotland in particular, and the role of James Watt, Musson and Robinson, *Science and Technology*, ch.9 (see note 4), remains the most informative and detailed account.

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