

# Salt, Salt Making, and the Rise of Cheshire

by

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## INTRODUCTION

Man obtains salt (sodium chloride — NaCl) from sea water, from naturally occurring rock salt, and from brine formed when water dissolves rock salt. Salt is necessary for the maintenance of life. It enhances the flavour of food. It preserves food by being toxic to micro-organisms and restricting their growth.<sup>1</sup> Salt has long been used in agriculture, glazing pottery, curing leather and dyeing textiles. Its use in the manufacture of heavy chemicals dates from 1773 when Scheele isolated chlorine from salt. Chlorine bleaching became a feasible industrial process after 1799 when Tennant patented bleaching powder.<sup>2</sup> In 1791 the introduction of the Leblanc Process for making soda from salt gave rise to the synthetic alkali industry.<sup>3</sup>

## SALT FROM SEA WATER

Sea water is a dilute solution containing about 3.5% salts.<sup>4</sup> When evaporated it becomes more concentrated and each salt is deposited at its saturation point (Table 1).

It is necessary to evaporate about 38kg of sea water to produce 1kg of salt. In lands with a dry season sea water may be evaporated to dryness by sun and wind. On San Francisco Bay, with a Mediterranean climate, Cargill Salt produces salt by fractional crystallisation. Sea water is held in shallow 500 acre ponds. At a concentration of 26.5%, when about 90% of the water has evaporated and calcium carbonate and calcium sulphate have precipitated out and settled, the brine is transferred to 40 acre 'harvesting ponds' and held until it reaches a concentration of 30%. At this stage about 90% of the salt has crystallised and settled, but the greater part of the 'bittern' salts (primarily magnesium chloride, a bitter and hygroscopic salt) remain in solution. The salt is harvested and washed with saturated brine to remove the bittern adhering to the grains. The bittern is drained from the pond. The wet salt is held in stacks for two to three months to drain. The salt, with a sodium chloride content of about 99.4%, is then crushed and graded to required particle sizes.<sup>6</sup>

Cargill's method has features similar to those employed by Mediterranean salt makers in the first century. Pliny referred to the evaporation of sea water in ponds, to ponds flushed with fresh water or sea water, and to salt allowed to stand in rain and dew to make it 'sweet'.<sup>7</sup> Solar salt, or 'bay' salt, was imported from Biscay into England and Scotland in the fourteenth century, although it seems likely that the trade was already of long standing; England was trading with Mediterranean merchants as early the seventh century BC.<sup>8</sup> Bay salt was highly valued for salting provisions such as fish. The large grains produced by slow

TABLE 1  
The Deposition of Salts during Evaporation of Sea Water (proximate values)<sup>5</sup>

Volume Range (%)	Salts Deposited	Fraction of Total Salts deposited (%)
100–20	calcium carbonate	0.3
21–3	calcium sulphate	4.5
9–1.5	sodium chloride and bittern salts (MgSO <sub>4</sub> /KCl/MgCl <sub>2</sub> /other salts)	70.5 2.6
Residual solution	sodium chloride bittern salts	6.7 15.3

evaporation and draining were reasonably free from bittern salts and dissolved relatively slowly, keeping the fish apart and allowing better distribution of the brine. It has been conjectured that of some 40,000 tons of salt consumed in England in the 1520s two-thirds was probably bay salt.<sup>9</sup> In 1628 it was stated that, '[w]ithout the salt from France, the whole salt-fish trade of the English would be destroyed'.<sup>10</sup> Besides the fisheries, bay salt was necessary to supply towns such as London and Bristol, and was used at coastal salterns to strengthen sea water to economise fuel.

In Britain, where climate does not favour solar evaporation, evaporation of sea water has always been completed in heated pans. Debris from prehistoric salt works has been found at coastal sites from Dorset to Lincolnshire. In Essex, excavation has revealed pottery fragments, carbonised wood, wood ash and salt-glazed clay. It is thought that salt was made there from the late Iron Age into the first century by concentrating sea water in open tanks and completing the process in crude pottery pans.<sup>11</sup>

Salt making continued at coastal sites through Roman times into the nineteenth century. In 1086 some 200 salines from Devon to Lincolnshire were recorded.<sup>12</sup> In 1270 175 'wichewerks' were operating at Lymington, Hampshire.<sup>13</sup> In the seventeenth century Lymington was a major centre of production. Around 1690 Celia Fiennes wrote,

the greatest trade is by their Salterns: . . . they fill them out of the sea at high tides and so conveyed from pond to pond. . . it stands for the Sun to exhale the watry fresh part of it, and if it prove a drye summer they make the best and most Salt for the rain spoyles the ponds by weakning the salt. . . when they think its fit to boyle they draw off the water by pipes which conveys it into a house full of large square iron and copper pans, . . . under which is a furnace that burns fiercely to keepe these panns boyling apace, and as it candy's about the edges or bottom so they shovell it up and fill it in great Baskets, and so the thinner part runs through on Moulds they set to catch it which they call Salt Cakes; the rest in baskets drye and is very good Salt.<sup>14</sup>

Depending on the weather the season lasted 15 to 20 weeks.<sup>15</sup> At nearby Portsea, in a 'seasonable' year, 'Every tonn of bryne maketh foure bushells of salt'.<sup>16</sup> Assuming 1 ton = 40 bushels, it would have been necessary to reduce the bulk of sea water by about two thirds to produce a brine of this strength.

On the west coast of Britain the moist Atlantic air gave little opportunity for concentrating sea water by solar evaporation. (The average rainfall from April to September at Sellafield, Cumberland 1951–80 was 481 mm; at Shoeburyness, Essex 1941–70 it was 277 mm.<sup>17</sup>) From an early time salt makers strengthened sea water by repeatedly passing it through salt-encrusted sand.<sup>18</sup> In the 1530s Leland, describing the process employed at the mouth of the River Cocker, Lancashire, referred to 'heaps of sand taken from the salt shore'

and to 'several salt-houses' where, 'by frequent soaking with water they dissolve the salt, channel the water into a pit, and then boil it off'.<sup>19</sup> This tedious and inefficient process had ceased by about 1730; it could never compete with Cheshire salt.<sup>20</sup>

## ROCK SALT

Rock salt is a sedimentary rock laid down during the evaporation of an enclosed sea. It lies with other evaporites including limestone (calcium carbonate), gypsum/anhydrite (calcium sulphate), potassium, magnesium and calcium chlorides, with clay and sand. Evaporites, varying from thin annual deposits to beds of considerable vertical thickness have been deposited in every geological period from the Pre-Cambrian, and are presently forming in the Persian Gulf.<sup>21</sup> In England evaporites were deposited under desert conditions in the Permian and Triassic Periods, c. 290–248 and 248–206 million years ago respectively.

Towards the end of the Permian period a basin, that now extends from England to the Polish-Russian border, was invaded by the sea to create salt deposits underlying Teeside.<sup>22</sup> Rock salt was discovered at Middlesbrough in 1862 by a prospector boring for water. In 1985 ICI pumped brine from the Teeside salt field to nearby chemical plants.<sup>23</sup>

The Permian Basin continues to subside; marine vegetation and organisms that died during evaporation now lie with Permian evaporites. Underlying the evaporites are Carboniferous coal measures. At a depth of 3–4.5 km marine remains subjected to temperatures of 100–160°C have formed oil. At 5–6 km marine remains and coal, subjected to temperatures >160°C, have formed gas. Oil and gas frequently occur with marine evaporites. The extensive oil and gas fields beneath the North Sea occur where hydrocarbons are trapped in permeable reservoir rocks and migration to the surface has been blocked by an impermeable cap rock such as clay, sandstone or salt.<sup>24</sup>

The Upper Permian strata underlying Boulby on the North York Moors have undergone considerable change to form a potash seam — maximum thickness 20 m, at depths of 1200–1500 m, comprising 35–45% potash and 55–45% salt plus impurities — believed to have been formed by the upward and lateral migration of saline solution, and by 'differential plastic flow' of rock at temperatures >200°C. Cleveland Potash Ltd, in production since 1973, has the capacity to produce about 1 m tonnes of potash and 0.5 m tonnes of road salt a year.<sup>25</sup>

In the Triassic Period the sea invaded depressions to form the salt fields underlying Dorset, Somerset, Worcestershire, Staffordshire, Shropshire, Cheshire and Lancashire. In the Cheshire–Shropshire basin lie two major beds of rock salt. The top bed was discovered in 1670, the bottom bed in 1781. At Marston, Northwich, beds of about 25 m and 30 m thick lie at depths of about 40 and 70 m separated by shale and mudstone. The depth and thickness of salt beds in Cheshire vary considerably over quite short distances.<sup>26</sup>

## SALT FROM NATURAL BRINE

Natural brine is formed when water dissolves rock salt. At 15°C saturated brine contains about 26.5% sodium chloride.<sup>27</sup> Evaporating brine is a simple process. William Jackson, describing boiling in an iron pan at Nantwich, Cheshire in 1669, wrote

They first fill their Pans with Brine out of the Pitt: . . then they put into their Panns amongst their Brine a certain mixture, . . of Calves Cows and chiefly Sheeps blood, . . this bloody

brine,.at the first boyling of the Pann, brings up a scumm, which they are careful to take off with. . .a Loot [ladle]. . .when 'tis halfe boyled away, they fill their Panns again with new Brine. . .[and] a quart of Whites of Eggs. . .[and] boyle sharply, till the second Scum arise; then they scum of as before, and boyle very gently till it Corne; [crystallises]. . .when part of the Brine is wasted, they put into each Pann about a quarter of a pint of the best and strongest Ale they can gett: this makes a momentary Ebullition, and then they abate their fires. . .they boyle gently, till a kind of Scum come on it like thin Ice; which is the first appearance of the Salt: . . .So they continue, till there is but very little brine left in the Pann; then with their loots they take it up the Brine dropping from it and throw it into their Barrows, . . .made with flat cleft wickers, . . .they let it stand so for an hour and an halfe in the Trough, . . .where it drains out all the Leach-brine, then they remove it into their Hot-house behind their Works. . .this Salt weighs heavier, and melts not so soon. In the smaller pans. . .they generally boyle their brine more away. . .they take their Salt out of their Brine, and only harden it in their Hot-house, 'tis apter to melt away in moist Air. The Leach-brine, that runs from the Barrows, they put into the next Boyling, . . .for 'tis to their advantage, being salt melted, and wanting only hardning.<sup>28</sup>

### ADDITIVES AND SALT QUALITY

Salt quality depends on separating salt from foreign matter and the other salts in brine. Jackson referred to adding blood, ale, and egg whites to the brine. In 1746 Lowndes used blood, egg whites, ale, butter and alum, to make salt 'as good or better than French Bay-Salt'.<sup>29</sup> Blood and egg white trapped organic and earthy matter in a scum that could be skimmed off.

At saturation point salt crystals form on the surface of brine and may adhere to form a thin crust that restricts evaporation. A film of butter on the surface prevented crystals from adhering and allowed them to sink. When the crystals sank the pan was said to 'work'. The salt maker managed the furnaces and the brine to get the salt to work favourably. Also, at boiling point, internal vapour bubbles broke the surface with violence causing salt crystals to sink to become focal points for smaller less violent bubbles. Briskly evaporating ale also would have caused salt crystals to sink. As late as 1894 Thomas Ward, a Cheshire salt maker, said calves foot jelly was still occasionally used to clarify brine, and that alum helped to form 'larger and more solid crystals'. He observed that a very small quantity of soap, glue, resin and other substances 'will entirely alter the working of the brine, and change the quality of the salt', but he did not know why.<sup>30</sup>

Salt quality depends very much on separating it from the other salts. At Lymington salt put into baskets to drain was 'very good', and Jackson observed that salt allowed to drain for 1½ hours melted 'not so soon'. Salt makers also used leach liquor to produce low-grade salt. At Lymington the drained liquor was made directly into 'salt cakes'. At Nantwich the salt put in the hot house to dry before the liquor had drained was 'apter to melt away'. Producing both good and poor quality salt allowed the greatest quantity to be made from the brine and fuel used.

### MOTHER LIQUOR AND PAN SCALE

As fresh brine was put into the pan and salt was removed, the salts remaining in the mother liquor accumulated. In Cheshire it was usual to drain and wash the pan used for making fine

salt on a Monday morning to minimise contamination of the salt. The pan was also descaled.<sup>31</sup> This was necessary because above 20°C calcium sulphate is deposited from evaporating brine as anhydrite ( $\text{CaSO}_4$ ).<sup>32</sup> Anhydrite mixes with salt to form a hard almost insoluble scale that adheres to the pan surfaces and restricts the transfer of heat to the brine.<sup>33</sup> Agricola observed that the salt maker pounded the bottom of the pan every week to loosen the ‘incrustations’, otherwise the plates would overheat and ‘burn’.<sup>34</sup> An overheated pan would glow red through the brine, and then the furnace had to be damped down immediately to prevent pan failure. To avoid draining the pan and prevent loss of output some workers would step into the brine with a bucket strapped to each foot to ‘scab’ the scale with a pickaxe, sometimes with fatal consequences.<sup>35</sup>

### FINE AND COARSE GRAIN SALT

Fine salt was produced by rapid evaporation. By the mid-nineteenth century production of fine salt in Cheshire for cheese, butter and table use was a capitalist industry. A pan owner of a small works would enter into an agreement with a self-employed salt maker, a ‘lumper’. The pan owner supplied brine and coal, kept the pan and furnace in good repair, and bought the salt. The lumper would tend the furnace, stir the brine, rake the salt to the sides of the pan, and top-up the pan with fresh brine.<sup>36</sup> It was often his wife’s job to ladle the wet salt from the pan into tubs (wooden boxes with perforated bottoms) to allow the salt to drain,



Fig. 1. Filling wet salt into a tub. Middlewich c. 1960.

then to beat the damp salt into lumps and put them in a stove (hothouse) to dry. Emptying tubs and shaping the lumps was heavy work.

Each lump weighed about 45lbs. . . the women had about fifty to seventy of these to move in quick succession. . . In a little over two hours, working in almost total darkness, intense heat and strength-sapping humidity, each woman had shovelled, shaped and carried about a ton weight of wet salt. . . As soon as the salt was safely in the stove the women would return home to prepare breakfast and begin their household tasks. Each drought was about three to four hours forming in the pan, and before noon the women would be making their way back to the salt works. This time, and at the two later draws — afternoon and late evening — the women might have the additional task of raking the salt to the sides of the pan.

A lady at Droitwich remarked, ‘We did everything, tapped the squares, run ‘em in the stove, worked the pan, filled the tubs, just like a man . . . and sometimes fired the pan when the fireman was drunk’.<sup>37</sup>

Nevertheless, the conditions in a salt works were usually better than in many other occupations — pan houses were steamy but well ventilated; hot houses were dry and ideal for meal breaks; the lumpman worked at his own pace, without undue stress and noise. Salt making was an arduous but relatively healthy occupation.<sup>38</sup>

Coarse grain salt was made slowly at a relatively low temperature with minimum disturbance, to allow the grains to grow. At Stoke Prior Works in 1937 common salt was formed at 80°C over 2 days; quarter-inch (6 mm) fishery salt at 60°C over 3–4 days; and 1–2 inch (25–50 mm) ‘bay salt’ at 50°C for up to 4 weeks.<sup>39</sup>



Fig. 2. Lumps drying in hothouse. Middlewich c. 1960.

## THE ADOPTION OF COAL

The depletion of woodlands and scarcity of wood fuel obliged salt makers to use coal. Coal appears to have been adopted to evaporate sea water on the Firth of Forth and on the north-east coast of England by the early sixteenth century.<sup>40</sup> At brine sites coal was adopted about a century later. It was in use at Droitwich from about 1615, and at Nantwich by 1636.<sup>41</sup> In 1678 Rastell observed that

The fuel which was heretofore used [at Droitwich] was all wood, which since the Iron-works, is so destroyed that all the Wood at any reasonable distance will not supply the Works one quarter of the year, so that now we all use almost all Pit-Coals which are brought to us by land 13. or 14. Mile.<sup>42</sup>

The adoption of coal had a marked effect on salt making. First, it hastened the introduction of iron evaporating pans. Iron is more resistant to acid gases from burning coal, such as sulphur dioxide, than lead, and it withstands higher temperatures. Lead melts at 330°C, iron glows dark red at 600°C.<sup>43</sup> Second, it initiated a restructuring of the industry.

## EVAPORATING PANS

Evaporating pans in antiquity were made of clay. The amount of fuel used to fire clay pans to some 900°C may well have exceeded that required to evaporate the brine. Lead pans, more efficient evaporators than clay pans, were in use by the first century.<sup>44</sup> Lead is an easy metal to extract from its ore and shape and repair, it is not corroded by brine, and in moist air it acquires a film of lead carbonate and lead hydroxide that has some resistance to the gases from burning wood. The substitution of lead for clay pans substantially reduced fuel costs in salt making. It was a major technological advance.

Until the eighteenth century evaporating pans were small. Lead pans of Roman origin at the Salt Museum, Northwich, and the Nantwich Museum have surface areas of roughly 3 × 3 ft (0.9 m<sup>2</sup>), and a Roman salt pan discovered at Shavington, Cheshire and reconstructed, weighs about 118 kg, is 8 mm thick, and measures 100 × 90 cm (0.9 m<sup>2</sup>) × 14 cm.<sup>45</sup> In 1629 the Stewards and Jury at Northwich, seeking to curb over-production, ordered that pans were to be cast from a piece of lead weighing 10 stone (63.5 kg).<sup>46</sup> This would have formed a flat sheet 5 mm × 1 m<sup>2</sup>. In 1678 lead pans at Droitwich, were made from 5½ × 3 ft (1.5 m<sup>2</sup>) cast flat plates with the side and ends beaten up.<sup>47</sup>

Iron pans were probably in use at Shields in 1489.<sup>48</sup> It was not until the early 1630s that iron pans were introduced at Nantwich. In 1669 iron pans adopted at Nantwich 'in the memory of many alive' were 'something better than a yard square' (1 m<sup>2</sup>).<sup>49</sup> However, the stiffness of iron allowed pan size to be increased. By 1733 pans 12–14 ft long and 7–10 ft wide (8–14 m<sup>2</sup>) were in use in Cheshire; in 1748 riveted iron pans at Shields 21 × 12½ ft (24 m<sup>2</sup>) were said to be the largest in the kingdom; in 1780 a pan 24 × 15 ft (33 m<sup>2</sup>) at Northwich was reckoned to be 'only medium sized'; and in 1796 pans 40 × 27 ft (100 m<sup>2</sup>) were in use at Winsford and Northwich.<sup>50</sup> Larger pans were more economical in the use of fuel and permitted specialisation of tasks for furnacemen and pan operators. There appears to have been an optimum size depending on the kind of salt made. In Cheshire in 1894 pans to boil fine salt up to 40 × 27 ft (100 m<sup>2</sup>) were heated by as many as five furnaces. Pans for coarse salt were up to 70 × 26 ft (170 m<sup>2</sup>).<sup>51</sup> Variation in pan size was almost entirely in length because a pan had to be narrow enough for the salt to be raked to the sides and, because evaporation occurs at the surface, pans were rarely more than 0.3 m deep.

## EVAPORATING SEA WATER WITH COAL

From an early time salt was made on a small scale on the shores and islands of Scotland by evaporating sea water over peat and turf fires. Coal may have been used from about 1200.<sup>52</sup> Evaporating sea water with fuel was not usually an economic proposition; it needed some 6 to 8 tons of coal to produce 1 ton of salt, compared with 1 to 2 tons when evaporating strong brine.<sup>53</sup> It was, however, a convenient way of disposing of low grade coal that represented as much as one-sixth of the coal produced.<sup>54</sup> Salt making and coal mining became closely integrated and by the sixteenth century much of the salt made in Scotland was produced along the lower Forth. In 1630 Scottish pan masters and mine owners petitioned Charles I stressing 'the reciprocal dependence' betwixt the coal and salt works that employed 10,000 workers.<sup>55</sup> From 1714 to 1825 annual output averaged some 7000 tons, the greater part being for home consumption. Exports, mostly to northern Europe, peaked at about 3000 tons in the 1720s. Salt making in Scotland declined from the 1850s when faced with competition from Cheshire salt.<sup>56</sup>

On the north-east coast of England experiments to evaporate sea water with coal began in the early part of the sixteenth century and by the end of the century salt making had migrated to the mouths of the coal exporting rivers Tyne, Wear, Blyth and Coquet, to integrate with a thriving coal trade.<sup>57</sup> In the 1590s more than 1000 vessels were carrying coal as far as Plymouth.<sup>58</sup>

Northumberland salt, like Scottish salt, was not well regarded; it was frequently contaminated by soot and coal dust from the colliers that carried it to market. Between 1690 and 1730 shipments of salt from Newcastle averaged about 12,000 tons a year. This represented more than half of the salt shipped from the north-east coast ports. In 1721, a typical year, Newcastle shipped 13,095 tons; 44% went to London, 35% went to other ports in England and 21% was exported. Shipments declined to 4784 tons in 1754, and to 931 tons in 1790.<sup>59</sup> Salt making continued on a small scale into the 1860s using rock salt from Cheshire to strengthen sea water.<sup>60</sup>

Newcastle salt drove numerous small coastal salt works out of business. King's Lynn in 1653 was mentioned as 'a magazine of coal and salt for nine counties adjacent'.<sup>61</sup> Lymington on the other hand thrived into the nineteenth century. In 1749 a total of 6000 tons of salt was shipped from Lymington to London, the naval bases at Plymouth and Portsmouth, and overseas. In 1804, producing about 5000 tons, Lymington shipped 2100 tons across the Atlantic and 500 tons to Europe, while retaining the balance for home consumption. By 1813 the trade was in decline due to competition from Cheshire. By 1845 it was cheaper to bring salt by rail from Cheshire than buy local salt.<sup>62</sup> Lymington was able to compete with Cheshire into the nineteenth century because it had good access to markets and produced good quality salt, so much so that Stoke Prior produced its own version of 'Lymington Salt' as late as 1937.<sup>63</sup>

## SALT MAKING AT BRINE SITES

Droitwich, an important salt making site in the fifth century BC. continued so into the twentieth century.<sup>64</sup> In 1086 Droitwich was the most important salt making centre in England with some 236 salt pans, said to be producing about a 1000 tons of salt a year.<sup>65</sup> Droitwich



had the benefit of strong brine, the best of which yielded 'above a fourth part of salt',<sup>66</sup> a plentiful supply of wood from nearby forests; and access to local markets for salt — Birmingham, Leominster, Princes Risborough, Stratford-upon-Avon — as well as the wider market via the River Severn through Worcester to Bristol.<sup>67</sup> In 1678 output stood at more than 2000 tons, facilitated by the switch to coal and the adoption of iron pans.<sup>68</sup> Until 1695 the production of salt was regulated by the borough, then Robert Steynor broke the monopoly by sinking brine pits on his own land.<sup>69</sup>

In 1771 the Droitwich Canal to the River Severn was opened to bring in coal and take out salt. In 1825 output was about 9000 tons, it peaked at 120,000 tons in 1872, by 1895 it was down to 54,500 tons. The last Droitwich salt works closed in 1922.<sup>70</sup>

Salt was made in Cheshire in the fifth century BC.<sup>71</sup> In 1086 Cheshire appears to have been of little importance compared with Droitwich; Nantwich 'rendering' £21 and Middlewich and Northwich each rendering £8,<sup>72</sup> the reason being their inaccessible location. Nantwich retained its relative position in 1605 having 1296 pans compared with 642 pans at Middlewich and 449 at Northwich.<sup>73</sup> However, the adoption of coal caused the centre of gravity of salt making in Cheshire to shift northwards. By 1675 Northwich was said to be producing 300 tons of salt a week while Middlewich and Nantwich each produced little more than 100 tons.<sup>74</sup> Northwich had better access to Lancashire coal, and could ship salt to Liverpool at lower cost.

The price of coal was a cause for concern. In 1699 carriage overland from Lancashire to the River Mersey, then on the River Weaver by 'flat' to Frodsham Bridge, and then nine miles by wagon to Northwich added £0.20 to the pit-head price of £0.30 a ton, or £0.43 when carried the further five miles to Middlewich. The carriage of Staffordshire coal to Middlewich was equally costly at £0.42 a ton in summer and £0.50 in winter.<sup>75</sup> Nef's estimate that the carriage of coal by pack horse or wagon over ten miles doubled its cost, seems about right.<sup>76</sup>

There was keen interest by some to make the River Weaver navigable above Frodsham. Attempts to obtain an Act of Parliament in 1663 and 1670 failed. In 1699 a proposal by the owners and exporters of rock salt and the Liverpool and London salt makers to make the river navigable up to Northwich was successfully opposed by the Middlewich and Nantwich salt makers, and by some 3000 to 4000 coal-carrying families. There was also concern that Cheshire white and rock salt would be so cheap that it would 'spoil all other workes'.<sup>77</sup> An attempt in 1709 also failed. In 1720, a determined campaign supported by the City of London, the Corporation of Liverpool, and refiners of rock salt at sites in Essex, Suffolk, Devon, Somerset, Cornwall, North and South Wales, Ireland and 'many' other makers in the Kingdom, was successful.<sup>78</sup> The Weaver Navigation, opened in 1732, served Northwich and Winsford but stopped three miles short of Middlewich. Proposed extensions to Middlewich and Nantwich were never built and the salt trade in these towns went into decline.<sup>79</sup> The delivered price of coal was further reduced in 1757 with the opening of the Sankey Canal to link collieries at St Helens to the River Mersey.<sup>80</sup> Canal transport was said to have reduced the costs of carrying goods to about one fourth of the previous rates.<sup>81</sup>

The Sankey Canal marked the beginning of a period of energetic canal construction. In 1761 the Duke of Bridgewater opened a canal from his colliery at Worsley to Manchester; it was extended to the River Mersey and Liverpool in 1762.<sup>82</sup> By 1813 Cheshire had access by canal to the industrial north, to London, and to Hull from where salt could be shipped cheaply to Newcastle and Scotland.<sup>83</sup>

## ROCK SALT MINING AND BRINE PUMPING

Another approach to reducing the costs of salt making was to find coal closer to the brine site. In 1670 a coal prospector fortuitously discovered the top rock salt bed at Marbury, two miles north of Northwich.<sup>84</sup> Rock salt was soon recognised as a substitute for bay salt.

The earliest recorded Cheshire salt mine was sunk near Northwich in 1682.<sup>85</sup> By 1689 rock salt was 'carried by sea to all parts of England and Ireland' and by 1697 it was refined at salt works on the Mersey. One problem was that shipping rock salt offered opportunities for smuggling and evasion of salt duty, and in 1701 refining rock salt was restricted to those works already using rock salt, and to new works within ten miles of the salt pits. This restriction applied until the duties on salt were finally repealed in 1825.<sup>86</sup> Nevertheless, in 1799 it was exported to Hamburg and Rotterdam, and Bideford refiners stated that the greatest part of the county of Devon was furnished with salt refined from rock.<sup>87</sup>

Rock salt mining in the eighteenth century was a speculative business

Rock-salt pits are sunk at great expence, and are very uncertain in their duration, being frequently destroyed by the brine springs bursting into them, and dissolving the pillars, by which the whole work falls in, leaving vast chasms on the surface of the earth. [The salt was blasted by gunpowder with pillars of salt being left to support the roof.]<sup>88</sup>

The collapsed workings flooded to become brine reservoirs, and the mine opened in 1682 flooded in 1720. By the end of the eighteenth century brine pumping from flooded mines resulted in land subsidence, extensive water filled 'flashes', and collapsed buildings.<sup>89</sup> Within a square mile beneath Northwich lie 90 abandoned rock salt mines and some 257 shafts, brine wells and boreholes that may lead to further massive subsidence.<sup>90</sup>

Today the Salt Union extracts brine from the bottom bed of rock salt underlying Cheshire, at Holford near Northwich, by controlled pumping to avoid subsidence. A lined borehole sunk to the base of the bed at about 350 m, contains two concentric tubes. Water pumped down the outer tube dissolves the salt, and the brine is forced up the inner tube. The brine reaches full strength in 3–5 years. Compressed air pumped down the space between the outer tube and the borehole forms an air barrier at the top of the cavity that restricts brine formation to the bottom and sides. Raising the water tube controls the shape of the cavity. At the end of its life of about 25 years a pear shaped cavity remains with a maximum diameter of 150 m and height of 180 m. Boreholes spaced 200 m apart leave 80% of the salt in place to support the surface layer. Support is also maintained by leaving disused cavities filled with saturated brine.<sup>91</sup> The brine is treated at Lostock to remove calcium and magnesium, and then pumped 15 miles by pipeline to Weston Point near Runcorn on the River Mersey. Weston Point works was established in 1910 to avoid trans-shipping salt from Weaver flats to deep water vessels, and to be away from a subsidence area.<sup>92</sup> About 70% of the brine extracted goes directly to chemical works.<sup>93</sup>

At Winsford the Salt Union operates the only rock salt mine in Britain. Salt is drilled and blasted from the bottom bed at a depth of 150 m. The mine opened in 1844, ceased production in 1892, reopened in 1928 and, until 1955, annual output was seldom more than 50,000 tonnes. Then began a rapid rise in demand for clearing snow and ice on roads. The mine has the capacity to produce 2.5 m tonnes of rock salt per annum. The salt, screened for mechanical spreading, consists of a balanced mixture with small particles for rapid action and larger particles for prolonged effect. Some rock salt is used as fertiliser for sugar beet, fluxing agent in non-ferrous metals, and in animal feed compounds.<sup>94</sup>



Fig. 3. Subsidence, Northwich c. 1900.

### THE RISE OF THE CHESHIRE SALT TRADE

The opening of the Weaver Navigation in 1732 and the Sankey Canal in 1754 lowered freight costs and gave better access to markets at home and overseas. 1732 marked the beginning of a rising trend of salt shipments on the Weaver, and the decline of salt making in Northumberland and Durham. Newcastle shipped 13,724 tons of white salt in 1694, 11,114 tons in 1729, and 931 tons in 1789. Northwich and Winsford shipped 5202 tons of white salt on the Weaver in 1732, 8279 tons in 1744, and 63,700 tons in 1789. Northwich alone shipped 13,310 tons of rock salt in 1747 and 47,730 tons in 1789.<sup>95</sup> Cheshire dominated the salt trade. By 1818 Cheshire was delivering salt to London at a lower price than Droitwich.<sup>96</sup> By 1825, of 75 salt works evaporating brine, 67 were in Cheshire and six at Droitwich; of 23 works refining rock salt 13 were at coastal sites; of 35 works evaporating sea water 14 were at Lyminster. In Scotland 15 works evaporated sea water.<sup>97</sup>

### STOKE PRIOR, WORCESTERSHIRE

The opening of salt works at Stoke Prior on the banks of the Worcester and Birmingham Canal in 1825, anticipating the repeal of the salt duties, indicates the importance of location. The site was ideal for producing salt. Rock salt and strong brine were available on site and coal could be brought into the works by canal boat. Similarly salt could be shipped directly to Birmingham, Bristol and London. Firms on both sides of the canal produced salt and

chemicals from the 1830s to the 1850s, after which they concentrated on salt making. The opening of a branch of the Midland Railway into the works in 1846 allowed coal to be delivered directly to the furnaces, and salt to be delivered in small lots to customers' works. In 1889 Stoke Prior was one of 65 works acquired by the Salt Union. In 1950 a triple effect vacuum plant was installed. In 1956 salt making in open pans ended and in 1972 the Stoke Prior works were closed by ICI as part of a rationalisation programme and to avoid the risk that further extraction of brine would cause land subsidence.<sup>98</sup>

### FUEL ECONOMY

Fuel was a major item of cost. Much of the heat from the furnace did not heat the pan but went up the chimney, and the heat that did evaporate the brine was dissipated in steam and lost in the salt taken from the pan. Between 1622 and 1866, some 85 patent applications were made concerning fuel economy. Invariably they related to furnace and flue design, multiple pans, and the use of steam heat.<sup>99</sup> For example:

1706 — D. Peck (Patent 375) proposed erecting a salt pan above a 'reverberatory air furnace whereby a much less quantity of coal is expended'.

1741 — J. Ogle (Patent 574) proposed directing heat from the furnace by flues to heat two pans, one to pre-heat the brine, the other to make the salt.

1783 — R. Vazie (Patent 1384) proposed to heat a series of pans by flue gas and steam.

Over time fuel was used more efficiently. In the 1670s Lord Brereton calculated that  $\frac{3}{4}$ – $1\frac{1}{2}$  tons of coal were used in Cheshire to make 1 ton of salt in an open pan; by 1915 consumption of coal had been reduced to  $\frac{1}{2}$  ton.<sup>100</sup> The amount of coal used depended on the quality of the coal, the strength of the brine, the type of salt made, the extent to which the pan was operated continuously, and the skill of the furnace man.

### NEW TECHNOLOGY — VACUUM EVAPORATION

When atmospheric pressure above a liquid is lower than the vapour pressure of the liquid, the liquid will boil. Evaporating brine under partial vacuum in a closed vessel is a means of economising on fuel. The first single effect vacuum evaporator, patented by E.C. Howard in 1812, designed and constructed in collaboration with Boulton & Watt, was erected at Liverpool to refine sugar in 1813.<sup>101</sup> The first multiple effect evaporator for refining sugar was installed in 1834.<sup>102</sup>

In 1839 J. Reynolds was granted Patent 8155 for 'Certain improvements in the manufacture of salt'. His specification states

steam produced by boiling brine in a closed vessel transfers its heat. . . [through] a vessel of thin metal immersed in the brine in a second closed vessel. . . so that the steam from such a second closed vessel may in a like manner transfer its heat to brine in a third vessel and so on, by maintaining in each of a series of closed vessels. . . such relative pressure as will cause the respective boiling points of the brine contained in each to be lower from the first to the last of the series.

British Salt at Middlewich operates a six-effect vacuum plant. Each effect holds brine and is connected to a steam chamber (calandria) fitted with tubes of large surface area that transfer heat from steam to brine. Steam passed into the calandria of the first effect heats the brine circulating through the tubes. The brine is held at boiling point, and at saturation point salt crystals settle to the bottom of the effect. The steam in the calandria loses heat and condenses to water and is returned to the boiler house. The vapour from the brine in the first effect is piped to the calandria in the second effect where its heat is transferred to brine. As the vapour from the first effect loses heat it condenses and produces a reduction of pressure in the first effect. The vapour from the brine in the second effect passes into the calandria of the third effect, and so on. The steam from the brine in the last effect is condensed by cold water causing further reduction in pressure. In theory the plant develops its own vacuum; in practice plant leakage and dissolved gases make a vacuum pump or steam ejector necessary.<sup>103</sup>

A vacuum system uses fuel more efficiently than an open pan. It is a closed insulated system that can utilize waste steam from another process to boil brine and to dry salt. When

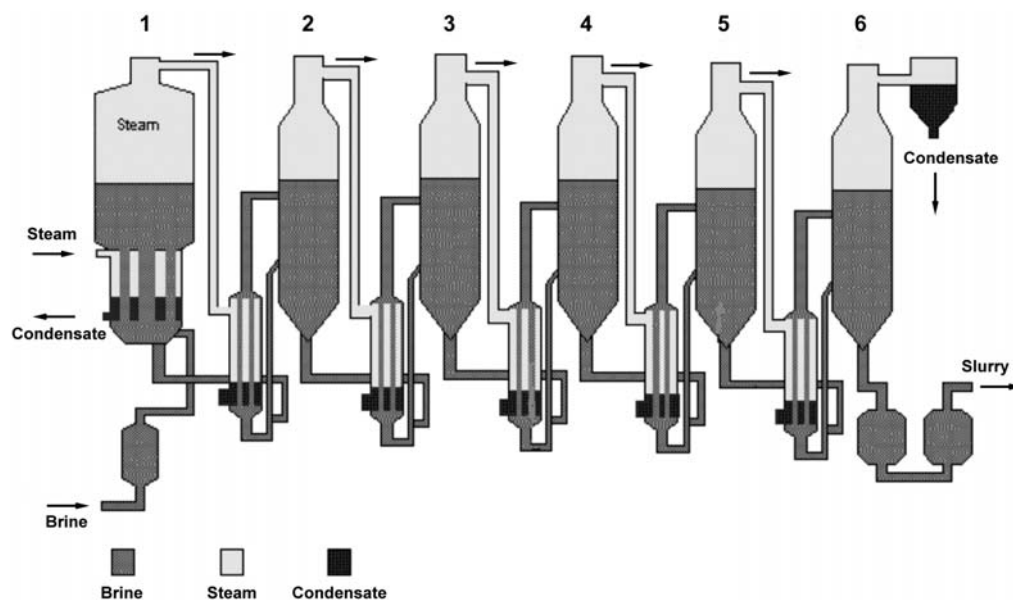


Fig. 4. A Typical Six Effect Vacuum Evaporation System (based on diagram from [www.saltinfo.com](http://www.saltinfo.com)).

TABLE 2

Temperatures and Pressures in a Typical Six Effect Evaporation System (Fig. 4)<sup>104</sup>

Effect	1	2	3	4	5	6
Temp. of steam entering calandria (°C)	173	147	124	104	84	64
Vapour pressure in effect (mb)	2758	69	-102	-576	-847	-972

the generating and vacuum plant were installed at Weston Point in 1910, the Mersey Power Company was formed to sell the electricity produced.<sup>105</sup> Further economy in the use of energy is obtained by operating multiple effects. The number of effects in operation will depend on the temperature of the steam used to heat the first effect, the heat loss in the system, and the boiling point of the brine in the final effect. In a six-effect system 1 unit of steam evaporates between 1 and 6 units of water. At Stoke Prior it was found that the vacuum plant used 20% of the fuel needed to make the same amount of salt in an open pan.<sup>106</sup> Further advantages are that steam condensate can be used for other purposes such as boiler water, and that the system is continuous and needs to be shut down only for maintenance. A vacuum system also uses labour efficiently. At Stoke Prior in the 1950s four men working an open pan produced 42 tons of fine salt a week; four teams of five men working the vacuum system produced 2500 tons.<sup>107</sup>

Salt crystals suspended in saturated brine (slurry) are drawn through to the end of the system where the salt is separated and partially dried by centrifuge. The separated brine is returned to the evaporators, or purged if the sulphate content is high. Vacuum salt, resembling wet sand, with moisture content below 3% is sold as UV salt (undried vacuum) for industrial use. Free-running salt for food preparation and table use, PDV (pure dried vacuum), is dried to a moisture content below 0.05%.<sup>108</sup>

It is usual to add anti-caking agents to PDV salt. In 1892, G. Weddel (Patent 12063), proposed adding sodium phosphate to salt. It reacted with deliquescent magnesium chloride, to produce salt, and magnesium phosphate that has some dietary value. Cerebos Salt Works at West Hartlepool added sodium phosphate to 'fine table salt' from 1894. Calcium phosphate and magnesium carbonate, at about 1%, are standard free running agents. In the 1950s Stoke Prior added sodium ferrocyanide to vacuum salt at 4ppm to prevent caking. Handling costs were reduced because it permitted pneumatic handling and transport in bulk. Potassium iodide, added up to 0.01%, remedies iodine deficiency that can cause goitre.<sup>109</sup>

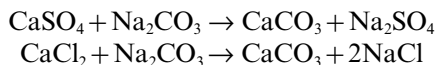
### TARDY ADOPTION OF VACUUM EVAPORATION

Salt makers in the 1840s showed little interest in Reynolds' patent. The first vacuum plant for evaporating brine was installed in the United States in 1887<sup>110</sup> and it was not adopted commercially in England until almost a century after it was first used to refine sugar. Possibly the first brine evaporator installed in England was a single effect designed by 'Dr Sigismund Pick of Szczkowa, Austria' [sic] erected about 1890 at a salt works in Staffordshire. It was a continuous process with the vacuum maintained by a pump. Even when the effect was not heated by exhaust steam from a steam engine, it was claimed that less than ¼ ton of coal was required to produce 1 ton of salt, compared with ½–¾ ton to make fine white salt in an open pan.<sup>111</sup>

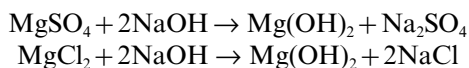
James Hargreaves installed the first vacuum plant at Middlewich in 1901. There appear to be two possible explanations for the delay. The first is that brine, unlike sugar syrup, contains calcium and magnesium ions capable of forming calcium sulphate that would block the tubes, and calcium and magnesium chlorides that would make the salt damp and bitter. In modern salt works calcium and magnesium are removed by chemical treatment before evaporation using sodium carbonate and caustic soda or slaked lime.

THE TREATMENT OF BRINE BEFORE EVAPORATION UNDER VACUUM<sup>112</sup>

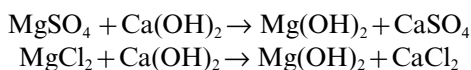
A slight excess of soda ash (sodium carbonate) is added to the brine to react with calcium (that would otherwise form calcium sulphate and calcium chloride) to form calcium carbonate, sodium sulphate, and salt.



The treated brine carrying a precipitate of calcium carbonate is then treated with a slight excess of caustic soda (sodium hydroxide) to remove magnesium as magnesium hydroxide. This prevents the formation of magnesium sulphate and magnesium chloride.



In both reactions, the sodium chloride content is increased. Magnesium hydroxide and calcium carbonate are then removed by flocculation, or allowed to settle in a pond. The treatment introduces sodium sulphate into the brine; care must be taken to prevent its deposition in the evaporators. The treatment may also be effected with a mixture of sodium carbonate and sodium hydroxide. Alternatively, magnesium can be removed by treating with hydrated lime instead of caustic soda.



Lime is cheaper than caustic soda. The disadvantage is that it puts calcium into the brine.

Salt makers were aware of the use of sodium carbonate to treat brine some years before vacuum evaporators were used to refine sugar. In 1801 J. Manley (Patent 2524) proposed using 'a certain quantity of fixed alkali [sodium carbonate] whereby several of the earthy salts in the brine are precipitated and may be removed without much difficulty'. The calcium sulphate problem would not have been a major obstacle to the adoption of vacuum evaporators.

## OVERCAPACITY IN THE INDUSTRY

A more likely explanation for the delay appears to have been a lack of incentive. After the repeal of the salt duties in 1825 demand for salt increased. In 1823 Northwich and Winsford shipped 172,000 tons of white salt on the Weaver; by 1828 the figure had risen to 312,000 tons.<sup>113</sup> New people came into the industry. Over-capacity, already a difficulty, became a chronic problem. In 1828 William Furnival opened a salt works at Wharton, Cheshire with an estimated annual output of 130,000 tons that could be made at 'half the price which it can be manufactured at any other establishment in the Kingdom'.<sup>114</sup> In 1824 he had been granted Patent 5046 for a process using flue gases to assist evaporation, and steam from a lower pan to heat an upper pan; in 1825, Patent 5206 for 'Improvements in the manufacture of salt' (no specification); and in 1831, Patent 6086 for using a covered pan to pre-heat brine. The Cheshire salt proprietors formed a coalition, lowered their prices, and put him out of business.<sup>115</sup> Defeating Furnival was one episode in an ongoing struggle to restrict competition. Over the next half-century, 'the big men endeavoured by combination to crush out the

small men, and having temporarily succeeded, they have broken themselves in attempts to exterminate each other'.<sup>116</sup> In 1866 Timmins observed that

The number of 'small masters' in the trade, renders any effective combination among the manufacturers difficult. . . The Cheshire works are capable of producing a million tons per annum, but the supply being immensely in excess of the demand, many works are always standing both in the Cheshire and the Worcestershire districts.<sup>117</sup>

An attempt to bring order to the salt industry was made in 1888 when 65 manufacturers representing 90% of UK production came together to form the Salt Union. Prices were regulated, production was controlled, and works were closed, but to no avail. The Salt Union 'very quickly showed a total inability either to rig the market or make its business pay'. After 1896 only one dividend was paid to ordinary shareholders.<sup>118</sup> Market conditions did not favour investment in new technology.

### A TECHNICAL PROBLEM WITH VACUUM EVAPORATION

A triple effect plant was installed at Winsford in 1905 and a plant was erected at Weston Point in 1911. Yet as late as 1915 some in the salt trade had reservations as to the utility of vacuum evaporation. Calvert expressed the view that the Hodgkinson Process was markedly superior to 'all other processes'. (Hodgkinson's Patents 5011, 26,068 (1908), and 22,163 (1909), for a mechanical stoker, heat directed by a system of flues, and a series of closed and open pans, have similar features to Patent 3187 granted to W. Steel in 1808). Calvert had bought the patent rights and tried to work the process, but he abandoned it in 1919.<sup>119</sup>

In one respect Calvert was right; Hodgkinson's process could produce six kinds of salt 'at the same time in one operation' — Finest Table, Dairy, Common, Coarse for curing and two kinds of Fishery.<sup>120</sup> A vacuum evaporator boiled brine and produced only fine grain salt. In 1945, as well as nine vacuum plants, there were 18 open pan plants at work in Britain to meet the demand for coarse grain salt in chemical manufacture and for the export market.<sup>121</sup>

The inability to produce granular salt by vacuum was overcome by the installation of an 'Oslo' evaporator, invented by F. Jeremiassen at A/S Krystal, Oslo, as a final effect at the ICI plant at Stoke Prior in 1950. The crystals were suspended in an upward flow of brine until they had grown to 1.5 mm diameter. This allowed ICI more flexibility in production and entry into an expanding market for granular salt for water softeners.<sup>122</sup> In 1958 ICI expanded the plant at Weston Point by adding three Oslo evaporators as the 'fourth' effect.<sup>123</sup> By 1970 salt making in open pans in Cheshire had almost ceased, the last to close in 1986 being the Lion Salt Works at Marston.<sup>124</sup>

### MODERN SALT PRODUCTION

A vacuum evaporator is efficient when operated at its designed capacity over its lifetime. At the planning stage this requires a decision to be made about future demand for salt. In 1976 ICI expanded the plant at Weston Point to six effects with the capacity to produce 1,095,000 tonnes a year. British Salt, the other major producer, opened at Middlewich in 1969, initially with five effects with the capacity to produce 600,000 tonnes a year. In 1975 the plant was expanded to six effects to produce 800,000 tonnes and began taking brine from a new brine



field at Warmingham; in 1976 capacity was raised to 824,000 tonnes. However, sales of white salt in the United Kingdom, after reaching a peak of 1.53 m tonnes in 1979 declined to 1.06 m tonnes in 1984. This may be attributed mainly to a fall in demand by the chemical industry where brine had been substituted for UV, and to concern about the use of salt in food and its effect on health. In 1979 ICI was operating at 84% capacity and by 1984 it was down to 64%. In the same years British Salt operated at 90% and 69% capacity. There was little expectation that future sales would return to previous levels.<sup>125</sup>

## CONCLUSION

To maximise profit manufacturers need to obtain raw materials, produce goods, and distribute them at least cost, and this is reflected in the evolution of British salt making. Salt making is a weight losing process and the location incurring least transport cost is the source of the sea water or brine. When wood was used as fuel there was little opportunity to increase output either locally or nationally. The adoption of coal removed this restriction and allowed salt makers to increase output to serve a wider market. Coastal sites evaporating sea water with coal had access by sea to new markets but this advantage persisted only so long as poor internal communications prevented lower cost producers at brine sites from entering these markets. Salt makers have continually sought to reduce fuel consumption: by adopting lead pans, by seeking ways of conserving heat in pan design and layout, and finally by vacuum evaporation. Over-production has been a chronic problem with salt making. To maintain prices boroughs imposed rigid controls on salt production. Later, salt makers combined to exclude newcomers from the industry. Vacuum salt makers are now obliged to operate below capacity and appear likely to do so for the foreseeable future.

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117. S. Timmins, op. cit. (70), p. 143.
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122. *The Times Review of Industry* (May 1953). Solvay S/A, Belgium, have modified the ‘Oslo’ method to produce ‘pearls’ with a diameter of 5–10 mm. European Paternrts 1989, 1991. <[www.solvay.com/salt](http://www.solvay.com/salt)> (2003).
123. White Salt U.K., op. cit., (23), p. 94.
124. White Salt U.K., op. cit. (23), p. 16. The Lion Salt Works Trust, a registered charity, is presently restoring the works <[www.lionsaltworkstrust.co.uk](http://www.lionsaltworkstrust.co.uk)> (2003); Maldon Salt in Essex continues to make salt on a small scale by evaporating sea water in open pans.
125. White Salt U.K., op. cit. (23), pp. 11, 20–31, 48, 80, 94.