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Sodium Bicarbonate Market Research in CIS

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Introduction

Sodium bicarbonate (Natrii hydrocarbonas). Synonyms: baking soda, bread soda, cooking soda, bicarbonate of soda, sodium hydrogen carbonate, Natrium bicarbonicum, Natrium hydrocarbonicum, Sodium bicarbonate. Sodium bicarbonate is a white solid that is crystalline but often appears as a fine powder without odor, with slight alkali taste. It is water-soluble (1:2) with formation of alkaline solution (pH of 5% solution 8,1), practically non-soluble in spirit.

$NaHCO_3$ is a white crystalline powder with density of 2.16-2.22 g/sm^3. When heated over 50°C, CO_2 starts being released, and when heated up to 100-150°C it gets decomposed completely, turning into Na_2CO_3. Water solutions of $NaHCO_3$ boast slight alkaline reaction.

Sodium bicarbonate was first classified by a German druggist B. Rose in 1801. In industry it is obtained by running CO_2 under pressure into saturated solution of Na_2CO_3 under 75°C:

$Na_2CO_3 + CO_2 + H_2O = 2\ NaHCO_3$.

Sodium bicarbonate $NaHCO_3$ (baking soda) is primarily used as a source of carbon dioxide in processes of bread baking, pastry baking, producing carbonated beverages and artificial mineral water, as a component of fire extinguishing compounds and medicinal agents. This is attributed to its easy decomposition (at 50-100°C).

I. Production technology for sodium bicarbonate and raw materials used in the Industry

I.1. Manufacturing practice for sodium bicarbonate

Sodium bicarbonate properties

Sodium bicarbonate $NaHCO_3$, called sodium hydrocarbonate in pure form, is generated as a transitional product in the process of soda ash production through saturation of ammoniac-saline solution with carbon dioxide. Sediment separated from mother waters (that is called raw bicarbonate on plants) contains a number of admixtures: sodium chloride, ammonium chloride, iron salines, insoluble matters and others. In the process of raw bicarbonate drying, practically all the admixtures remain in the product. Therefore, its compound does not meet the requirements set forth by consumers in a number of cases and consequently needs purification.

Production of rectified sodium bicarbonate is closely associated with sodium production, since soda ash, or raw bicarbonate and carbon dioxide of calcic furnaces are used in $NaHCO_3$ production process. That is why workshops for pure sodium bicarbonate are placed at sodium plants.

Sodium bicarbonate presents itself as white crystalline powder with average crystal size of 0.05-0.2 mm. Its molecular weight stands at 84.01, density at 2,200 kg/m^3, apparent density 0.9 g/sm^3. Sodium bicarbonate heat of solution is 205 kilojoule (48.8 kcal) for a kilo of $NaHCO_3$, heat capacity 1.05 kilojoule/kg·K (0.249 kcal/g·°C).

Sodium bicarbonate is thermally low stable and when heated becomes decomposed with formation of solid sodium bicarbonate and with emission of carbon dioxide and water into gas phase:

$2NaHCO_3$ (solid) ↔ Na_2CO_3 (solid) + CO_2 (gas) + H_2O (steam) – 126 kilojoule (1)

(-30 kcal)

Water solutions of sodium bicarbonate decompose similarly:

$2NaHCO_3$ (solution) ↔ Na_2CO_3 (solution) + CO_2 (gas) + H_2O – 20.6 kilojoule (2)

(-4.9 kcal)

Water solution of sodium bicarbonate has slight alkaline character; therefore, it does not interact with animal or plant tissue. Solubility in water is moderate. With temperature increase, it grows slightly in size. Tables 1 and 2 shows data on solubility of NaHCO3 and Na2CO3 in water at different temperatures.

Table 1: Solubility of sodium bicarbonate in water at different temperatures

Temperature °C	**Solubility of $NaHCO_3$**			**Temperature °C**	**Solubility of $NaHCO_3$**		
	g/100 g H_2O	**%**	**n.d.**[*]		**g/100 g H_2O**	**%**	**n.d.**
0	6.87	6.43	16.0	40	12.54	11.14	28.7
5	7.41	6.89	17.2	45	13.35	11.78	30.4
10	8.11	7.50	18.8	50	14.19	12.34	32.0
15	8.79	8.08	20.3	55	14.94	13.09	34.1
20	9.53	8.70	22.0	60	15.77	13.63	35.6
25	10.27	9.31	23.6	70	17.45	14.85	39.2
30	11.00	9.90	25.2	80	19.17	16.08	42.7
35	11.77	10.53	27.0				

[*] - concentration of salts is represented in normal divisions (n.d.). This concentration measuring is used at soda plants. One n.d. corresponds 1/20 g·equiv of matter in 1 liter of solution. Measurement of matter concentration in gram-equivalents simplifies calculations, eases browsing and comparative assessment of technical estimation and laboratory reports. For sodium bicarbonate coefficient of n.d. in g/l equals 4200, g/l in n.d. – 0,2381.

Source: Krasheninnokov S.A. "Technology of soda ash and purified sodium bicarbonate", 1985

Table 2: Solubility of sodium carbonate in water at different temperatures

Temperature, °C	**Solubility Na_2CO_3**	
	g/100 g H_2O	**n.d.**
20	22.95	83.5
30	39.20	144.0
40	48.90	182.0
60	46.50	173.0
80	45.40	170.5
100	45.20	170.0

Source: Krasheninnokov S.A. "Technology of soda ash and purified sodium bicarbonate", 1985

As can be seen from the comparison of the presented data, solubility of sodium carbonate (soda ash) at the same temperature is 3-5 times higher than solubility of sodium bicarbonate.

The density of saturated aqueous solutions of $NaHCO_3$ due to small solubility comparatively little differs from pure water density. Table 3 shows some values of aqueous solutions of $NaHCO_3$ at different temperatures.

Table 3: Density of NaHCO3 water solutions at different temperatures

Concentration of $NaHCO_3$, %	Density, kg/m^3 at temperature	
	18°	**50°**
1	1006	1006
2	1013	1013
3	1021	1020
4	1028	1027
5	1035	1034
6	1043	1041
7	1050	1048
8	1053	1055
10	-	1069
12	-	1084

Source: Krasheninnokov S.A. "Technology of soda ash and purified sodium bicarbonate", 1985

The following dependence of viscosity of water solutions of $NaHCO_3$ on their concentration at temperature 18° C is observed:

Concentration of solution, %	**2,06**	**4,03**	**7,75**
Viscosity, centipoise	**1,204**	**1,851**	**2,238**

Schematic diagram on obtaining purified sodium bicarbonate

Sodium bicarbonate is poorly water-soluble, and besides, it is thermally unstable; when it is heated, some part of it converts into soda, reducing $NaHCO_3$ solubility. The solubility of $NaHCO_3$ in presence of Na_2CO_3 at the temperature of 25° and 50°C is shown in Table 4.

On an industrial scale purified sodium bicarbonate is received by carbonizing soda solution according to reaction

$$Na_2CO_3\ (sol.) + CO_2\ (g.) + H_2O\ (liq.) \leftrightarrow 2NaHCO_3\ (sol.) + 52.4\ kJ \qquad (3)$$

(+12.5 kkal)

The application of the carbonization method allows sufficient reduction of the volume of liquid necessary for obtaining a product unit, as soda solubility is several times higher than solubility of $NaHCO_3$.

Table 4: Solubility of NaHCO3 with the presence of Na2CO3 at different temperatures

Temperature °C	Solubility $NaHCO_3$, %	Content Na_2CO_3, %	Temperature °C	Solubility $NaHCO_3$, %	Content Na_2CO_3, %
25	9.3	0.0	50	12.40	0.00
25	9.1	0.9	50	12.22	0.27
25	7.8	5.4	50	11.68	1.08
25	4.9	6.1	50	9.93	4.78
25	3.9	10.0	50	8.27	10.04
25	3.3	16.7	50	6.80	14.90

Source: Krasheninnokov S.A. "Technology of soda ash and purified sodium bicarbonate", 1985

Soda solution for carbonization can be obtained by dissolving in water solid technical soda, generated during calcinations of wet bicarbonate (“dry” method), or decomposition of bicarbonate in aqueous medium when heated under the reaction (2) (“wet” method). The latter process is called decarbonization. In industry both methods are used. The “wet” method is more appropriate, as it requires less heat for decomposition of $NaHCO_3$ with obtaining of Na_2CO_3 in solution.

The pure sodium bicarbonate, precipitating during saturation of soda solution by carbon dioxide, is separated, and the mother liquid containing $NaHCO_3$, Na_2CO_3 and dissolved impurity substances, for instance NaCl, are returned to the start of the process for getting initial soda solution. Because of multiple circulation of mother liquid, impurities are accumulated in it and likely to cause the appearance of these inclusions in the purified bicarbonate. That is why part of the mother liquid is withdrawn from the cycle and is usually directed to the brine cleaning for diluting of strong soda solution.

Physicochemical fundamentals of separate stages of production of purified sodium bicarbonate

The process of obtaining of initial solution by decarbonization of suspension of technical sodium bicarbonate. When water solution of sodium bicarbonate is heated, it transmits into soda according to the reaction (1), and the impurities contained in it, containing ammonia, are decomposed under reactions:

$$2NaCO_2NH_2 + H_2O \leftrightarrow Na_2CO_3 + 2NH_3 + CO_2 \qquad (4)$$

$$NH_4Cl + NaHCO_3 \leftrightarrow NaCl + 2NH_3 + CO_2 + H_2O \qquad (5)$$

Sodium and sodium chloride remain in the solution, and carbon dioxide and ammonia are removed from the solution into gaseous phase.

The decarbonization process is aimed at obtaining soda solution with maximum concentration of Na_2CO_3, possible at temperatures of the surrounding premises. It will approximately conform to the general alkalinity of the solution (as calculated for Na_2CO_3) 278 g/l, or 105 n.d. For obtaining soda solution of such concentration, the initial solution of sodium bicarbonate should contain at least 102 n.d. of $NaHCO_3$. This concentration more than three times exceeds $NaHCO_3$ solubility. Therefore, aqueous suspension of $NaHCO_3$ is used for its decarbonization. As the dissolved $NaHCO_3$ decomposes, new quantities of it will pass to the solution from the solid phase until it is fully dissolved.

Rising of temperature shifts the balance of the reaction (2) to the right. Therefore, the process of decarbonization is carried out in industry at temperatures close to the boiling point of the solution. Below is shown the dependence of the level of decomposition of sodium bicarbonate, or decarbonization level on the temperature and the time of the heating:

Temperature, °C	**102**	**102**	**102**	**102**
Degree of decomposition, %	**87**	**90**	**92**	**92**
Duration of heating, min	**30**	**40**	**50**	**70**

(The degree of the decomposition of $NaHCO_3$, or, which is the same, the degree of decarbonization, is determined by the ration of the content in n.l. Na_2CO_3 in the solution to its total alkalinity, expressed in per cent)

As can be seen from this data, the process of decomposition of $NaHCO_3$ does not proceed until the end and at high degrees of carbonization the rate of the process slows down.

The rate of decomposition of $NaHCO_3$, like the rate of any chemical reaction, depends on the temperature. Growth of temperature has a positive effect both on the shift of balance to the desired direction and on the rate of reaction.

The process of decomposition of $NaHCO_3$ is facilitated by removal from the liquid of the product of CO_2 reaction. The driving force of desorption process is the difference between the equilibrium pressure of desorbed gas (CO_2) above the liquid and its partial pressure in the gaseous phase. The more the difference, the more intensive is the process. Desorption continues until the equilibrium pressure of CO_2 above the liquid becomes equal to its partial pressure in the gaseous phase.

Equilibrium pressure of CO_2 above the solution containing Na_2CO_3 and $NaHCO_3$, as well as maximum obtainable degrees of decarbonization depending on the temperature and pressure of CO_2 in the gaseous phase can be calculated according to the following empirical equation:

$$\frac{X^2 C^{1.29}}{SP^*(1-X)(185-t)} = 26600 \qquad (6)$$

where X – content of sodium, present in the form of $NaHCO_3$; *(I - X)* – content of sodium, present in the form of Na_2CO_3, C – concentration of total Na в in solution, n.d.; t – solution temperature °C, S - solubility of CO_2 in water at temperature t and pressure P_{CO_2}, *equal to* 1 atm, mole/l; P^* – equilibrium partial pressure of CO_2 above the solution, atm. (The received values of P^* in atmospheres are recalculated into kiloPascals).

The solubility of CO_2 in water at the pressure equal 1 atm is the following:

Temperature, °C	**15**	**25**	**35**	**45**	**55**	**65**	**75**	**85**	**105**
Solubility, CO_2, mole/l	**0.045**	**0.033**	**0.026**	**0.021**	**0.017**	**0.015**	**0.012**	**0.009**	**0.001**

Table 5 shows equilibrium pressures of CO_2 above the solutions, containing Na_2CO_3 and $NaHCO_3$, depending on the temperature and degree of carbonization, calculated according to the equation (6). Calculations in the table are made for solutions, containing 1 g·equiv of total Na per 1 liter of solution. If Na concentration is increased by x times, partial pressures of CO_2 according to the equation (6) should be multiplied by $x^{1,29}$.

Table 5: Equilibrium pressure of CO2 over solutions, containing Na2CO3 and NaHCO3

Degree of decarbonization, °%	**Equilibrium pressure of CO_2 over solution, kilopascals (millimeter of mercury)**		
	at 20°C	**at 40°C**	**at 60°C**
10	12.6(95.00)	24(180.00)	40(300.0)
75	0.15(1.10)	0.24(1.80)	0.37(2.80)
90	0.01(0.13)	0.03(0.22)	0.04(0.32)

Source: Krasheninnokov S.A. "Technology of soda ash and purified sodium bicarbonate", 1985

Table 5 shows that increase of decarbonization degree results in sharp drop of equilibrium pressure of CO_2 above the solution, and when carbionization reaches 90% it makes only tenth of mm Hg. Therefore if decarbonization degree is increased, the driving force of desorption drops sharply, which greatly slows down the process of $NaHCO_3$ decomposition. Therefore in order to achieve high degrees of decarbonization not only high temperature, but long-time keeping of the liquid in the apparatus is needed, which can be achieve only in bubble-type apparatus (with bubble plates, with submerged muzzle and so on).

However in order to produce purified sodium bicarbonate it is not necessary to obtain high levels of decarbonisation, as the solution received further in a decarbonifier is subject to carbonization yielding $NaHCO_3$. The degree of decomposition of $NaHCO_3$ of about 85% or lower is enough.

The suspension of $NaHCO_3$ is heated up to the decomposition temperature by means of saturated water steam delivered to the suspension. During direct contact of the heating steam with liquid the intensity of the heat transfer increases, and CO_2 partial pressure in gas decreases, favorably affecting the intensity of the driving force of desorption, especially at the end of the decomposition process.

Carbonization of sodium solution.

Soda solution obtained by "wet" or "dry" method is subjected to carbonization for releasing $NaHCO_3$from it as solid phase according to the equation (3) for the reaction.

If in the process of decarbonization the limiting phase is desorption of CO_2 from solution, the rate of decarbonization is determined by the reverse process - the rate of CO_2 absorption. As is in case of absorption of CO_2 by the ammonized solution, the rate of absorption of CO_2 by soda solution at rising temperature, on the one hand, will rise, as the reaction rate grows and viscosity of the solution falls, facilitating introduction of the active CO_2 component to the surface of phases contact, - but on the other hand, will reduce, as the driving force of absorption diminishes – the difference of CO_2 pressures in carbonizing gas and above the solution. These two factors, acting in two opposite directions, indicate the optimum for carbonization temperature. It is found within the range of 80-60°C. The first temperature is related to the soda solution coming for carbonization and containing little bicarbonate with low CO_2 equilibrium pressure, while the second one is related to the final carbonized solution where the increased content of carbonate starts to influence noticeably, as the temperature grows, the equilibrium pressure of CO_2 above the solution, and therefore, to decrease the driving force of absorption.

The quantity of sediment $NaHCO_3$ produced by carbonization of soda solution depends on the concentration of the initial solution, on temperature and degree of carbonization, determined as the ratio of the total content of CO_2 in sediment and in the solution, to the general alkalinity of the initial solution.

This dependence may be expressed by the equation

$$x = 0.0088C_{init.Na}\ (R - 87) - 0.015t - 0.7, \qquad (7)$$

where x – quality of sediment $NaHCO_3$ in the initial solution, g·equiv/l;
$C_{init.Na}$ – alkalinity of the initial soda solution, g·equiv/l;
R – carbonization degree, %;
$R_c = (total.\ CO_2/total.\ Na)\ 100$;
t – temperature, °C.

Thus at temperature of 50°C and carbonization degree of 160% $NaHCO_3$ precipitates as a solid phase from each liter of soda solution with initial alkalinity 4.5 g·equiv/l:

$$x = 0.0088 \cdot 4.5\ (160 - 87) - 0.015 \cdot 50 - 0.7 = 1.44 \text{ g·equiv.}$$

It is evident that the higher the concentration of total Na in the initial solution and the lower the temperature of the suspension as well as its carbonization degree, the greater is the quantity of $NaHCO_3$ in the sediment. However, it should be noted that the final temperature of suspension is determined not by the quantity of the sediment sodium bicarbonate, but by its quality, therefore the level of carbonization is kept rather different from the equilibrium.

The significant operation in the process of obtaining purified sodium bicarbonate is crystallization of $NaHCO_3$. During crystallization of $NaHCO_3$ in the process of carbonization of soda solutions, direct dependence has been established between the rate of crystallization – W_{cr} and absorption of CO_2, as the latter determines the extent of the oversaturation of solution in $NaHCO_3$. On the other hand, the rate of crystallization of sodium bicarbonate influences the rate of absorption of CO_2, as in the process of crystallization of $NaHCO_3$ concentration falls of HCOi-ions adversely affecting the absorption of CO_2 by the solution. Crystallization of $NaHCO_3$ may be determined by hydrodynamic conditions – turbulization of the system (the intensity if its mixing), or the temperature. Under these conditions the rate of crystallization depends only on the temperature. For both regimes of crystallization behavior, called diffusion and kinetic, W_{cr} is generally expressed by equation

$$W_{кр} = K_k \Delta c^n, \qquad (8)$$

where K_{cr} – constant of $NaHCO_3$ crystallization rate; Δc – oversaturation of the solution in $NaHCO_3$, or the difference between the current and equilibrium concentration of $NaHCO_3$ in solution; n – index of power, equal for the diffusion regime 1 and for kinetic regime 2.

Experiments have shown that low mixing conditions result in crystallization process under diffusion-limited regime, whereas intensive turbulent mixing condition – under kinetic-limited regime.

Big and easily filtrated $NaHCO_3$ crystals are obtained if high temperature of carbonized suspension is kept (60-70 °C) until its exit from the carbonizing column. The construction of the canonizing column itself facilitates obtaining big $NaHCO_3$ crystals – with small amount of plates, providing for lengthways mixing of the liquid inside the column, the withdrawal of small $NaHCO_3$ crystals from the bottom part of the column to its upper part as inoculums, around which mass crystallization is going on. Oversaturation decreases, the rate of crystallization falls, and the crystals grow bigger.

Technological schemes of production of purified sodium bicarbonate

Technological schemes of production of purified sodium bicarbonate by means of “dry” and “wet” method differ mainly according to the procedure of preparation of the initial solution.

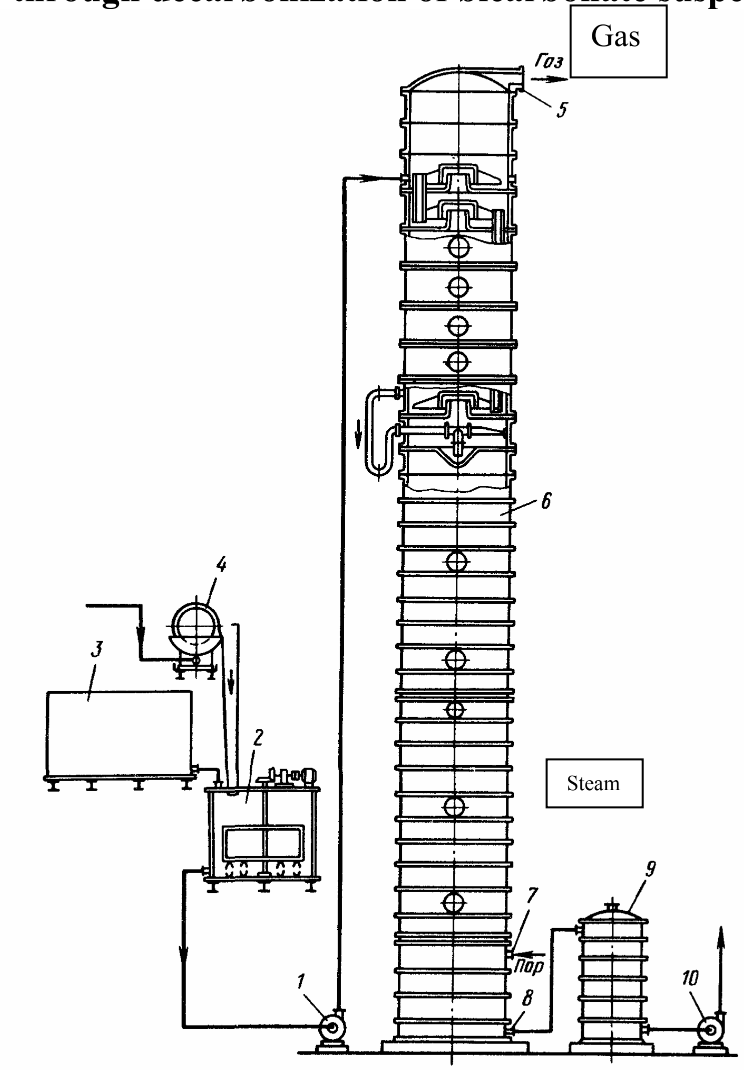
Production of purified sodium bicarbonate by means of “wet method”.

Figure 1 represents a schematic diagram of the compartment for preparation of initial sodium solution by decarbonization of bicarbonate suspension. Sodium bicarbonate from vacuum-filters *4* for sodium production is delivered to the reservoir with mixer *2* for preparation of suspension of $NaHCO_3$, where the “return” sodium solution from vessel *3* also enters. The proportion between the “return” solution and solid $NaHCO_3$ should provide for the total alkalinity of the prepared suspension of 110-115 n. d.

The prepared suspension of $NaHCO_3$ is pumped by centrifugal pump *1* to the top of decarbonator *6*. From the bottom through connector *7* water steam is fed under pressure of 3.9-4.9 Pa (0.4-0.5 atm), necessary for decomposition of $NaHCO_3$. Sodium solution having concentration of total alkalinity 105-110 n. d. goes out from the bottom part of decarbonator *6* to collector *9*, from where by pump *10* it is pumped out for production needs. The gases released from the top part of the decarbonizer contain up to 95-98 volume % of CO_2 as calculate for dry gas and some quantity of NH_3. Therefore, they are not allowed to be released into the atmosphere, but directed through connector *5* to the gas collector of furnaces for soda ash production. During production of 1 ton of standard soda solution about 415 kg of CO_2 and 20 kg of NH_3 is released.

Further processing of soda solution into purified sodium bicarbonate both under “wet” and “dry” method is the same, and includes the following operations: clarification of sodium solution, carbonization of sodium solution, filtration of sodium bicarbonate, drying of wet sodium bicarbonate, sizing (crushing), magnetic separation and packing of the ready product.

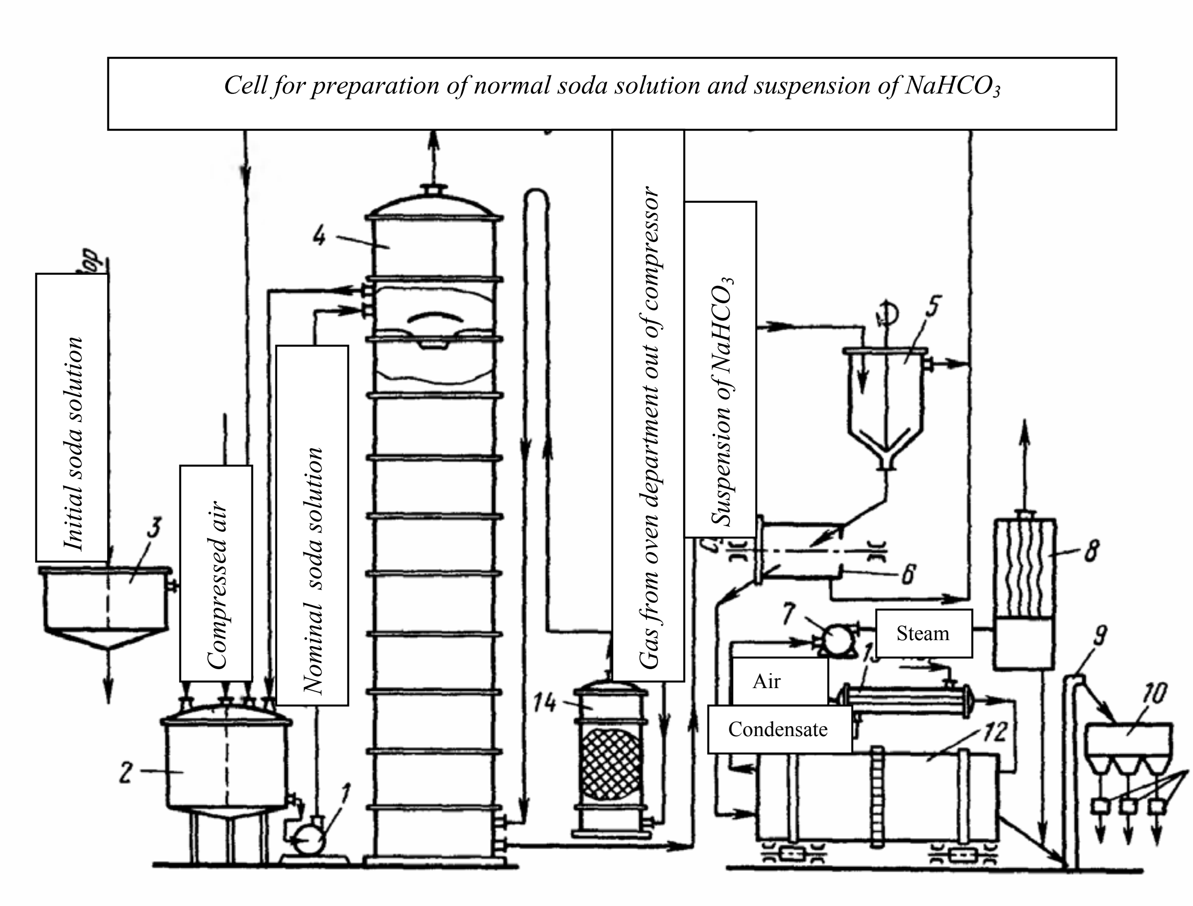
Figure 1: Flow diagram of an aggregate for sodium solution preparation through decarbonization of bicarbonate suspension



1, 10 - pumps, *2* – mixer for sodium bicarbonate suspension, *3* – vessel for solvent, *4* – drum vacuum -filter , *5* - connector for exit of steam-gas mixture *6* - decarbonator, 7 – connector for steam feeding, *8* - connector for sodium solution exit, *9* - collector

Figure 2 shows technological scheme of production sodium bicarbonate by means of “wet” method (without transport devices and some auxiliary apparatus). Sodium solution having total alkalinity of 105-110 n. d. is pumped *3* from carbonization compartment to the collector *3* of the initial sodium solution for settlement. Very small amounts of precipitation which are generated are withdrawn from time to time out of collector *3* and are delivered for using to the compartment of solution clarification. The clarified sodium solution from collector *3* is pumped to the two alternatively working collectors *2*, where normal sodium solution with total alkaline concentration of about 86 n. d. is prepared. Experience has shown that sodium solution of such concentration provides for high rate of CO_2 absorption, while production capacity of the carbonizing column stays rather high. For diluting initial sodium solution “return” solution is fed to collector 2, which is called weak liquid.

Figure 2: Flow diagram for production of rectified sodium bicarbonate through "wet"



1 - pump, *2* – collector for preparation of "normal" sodium solution. *3* – collector for the initial sodium solution, *4* – carbonizing column, *5* - precipitation-condensing tank, *6* - centrifuge, *7* - blower, *8* - bag filter, *9* - elevator, *10* – sizing seive, *11* – magnetic separator, *12* – drum dryer, *13* - heater, *14* – gas washer

For rapid mixing of liquids in tank *2* com*pressed air is delivered to it. From tank* 2 normal soda brine, called column liquid, by pump *1* is pumped to the top of carbonizing column *4*. Carbon dioxide from lime furnaces, cleaned from mechanical impurities in washer *14* is pumped from the bottom to the carbonizing column by the pump under pressure 24.5 Pa (2.5 atm). The content of CO_2 in carbonizing gas should be not less than 32%. Carbon dioxide is not fully absorbed in the column. Its content in the exhausted gas, released in the atmosphere is 16-20%.

The suspension of sodium bicarbonate, formed in the column, is diverted from below the column to the tank-thickener *5*. The requirement for $NaHCO_3$ suspension thickening before delivering it to the centrifuge is needed because for proper centrifuge operation the suspension should have proportion L:S= 1.1:1.0, as diluted suspension is difficult to filter and considerably reduces centrifuge production capacity.

The thickened part of the suspension (pulp) from the bottom of the tank-thickener *5* enters centrifuge 6 for separation. The sediment $NaHCO_{3,}$ if necessary, is washed with water, discharged from the centrifuge and is delivered to the dryer *12*.

The manifold and washing liquid from the centrifuge and clarified solution from the precipitation tank 5 go to the relevant tanks (not shown on Figure2), then they are mixed and in the form of the recirculated solution or weak liquid go to the vessel 2 for diluting soda solution and to the compartment of decarbonization for preparing of sodium bicarbonate suspension. The moister content of $NaHCO_3$ sediment discharged from the centrifuge is 2.5-3%.

For drying sodium bicarbonate drum driers are used, in which wet sodium bicarbonate during rotation of the drum is moving alongside it and is being dried by the coming hot air with temperature of 105-110 °C. At the exit from the dryer the air temperature falls to 55-59 °C. Dry sodium bicarbonate, unloaded from the drum drier by the elevator 9, goes to the sieve screen sizer *10*, where it is divided according to the size into several fractions. At some plants big size fractions are ground and after that it again goes to the sieve screen 10. Before packing sodium bicarbonate passes through magnetic separator 11 in order to remove random metallic fractions.

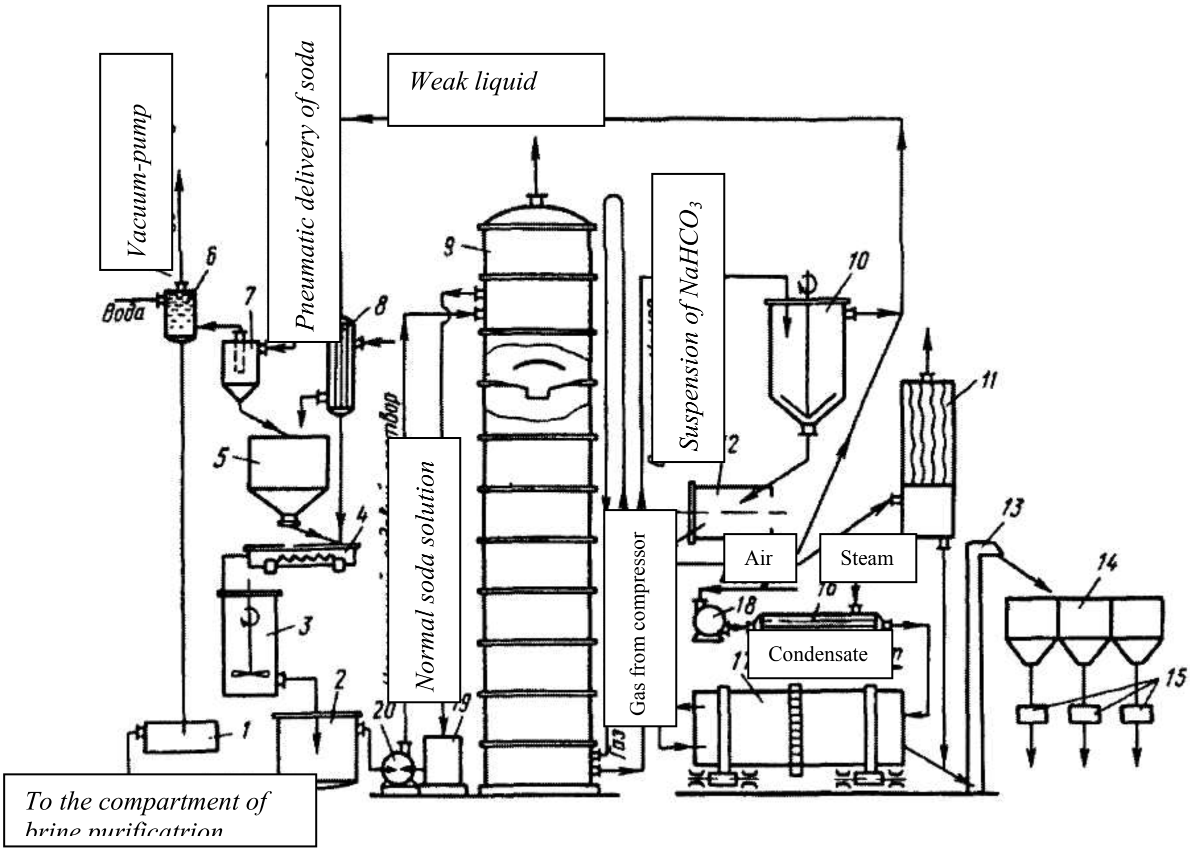
The air necessary for drying sodium bicarbonate passes through tube airheater 13, where it is heated by air steam up to 105-110 °C and by means of blower *7* penetrated through the dryer. Passing through the dryer, the air entraps up to 12% $NaHCO_3$, therefore before being discharged into the atmosphere it is passes through the bag filter *8*. From the filter the entrapped fractions of sodium bicarbonate get to the general current of $NaHCO_3$, going to the sizing. The use of counterflow in drum dryers reduces the removal of dust, as the counterflow makes the air going out of the dryer contact wet sodium bicarbonate fractions.

Dry method of sodium bicarbonate production.

Solid soda ash is pumped from the calcinations compartment to the cyclone *7* (Figure 3). The air cleaned from soda dust passes through the washer *6* and is inhausted by a vacuum pump (not shown on the figure). The washing liquid from the washer *6* is collected in the bucket *1* and is transferred to the cleaning brine compartment. Soda ash from the bottom of cyclone *7* passes to the soda bin *5*, from where it goes to screw diluter *4*. Weak liquid, heated in the heater *8* up to 90-95°C is used as solvent.

The prepared soda solution is delivered to the storage tank of normal soda solution *4* from where it passes to precipitation tank *2*. The clarified solution is pumped by the pump *20* to the top of the carbonizing column *9*. The excess of the solution from column *9* through overflow goes to the bin *19*. From the bottom carbon dioxide is pumped to the column by a gas compressor. The gas released from the column passes through a mist eliminator and is exhausted to the atmosphere. Sodium bicarbonate suspension from column *9* passes to precipitation-thickener *10*. The compacted precipitation $NaHCO_3$ goes to centrifuge *12* and then to the dryer *17*.

Figure 3: Flow diagram for production of rectified sodium bicarbonate through "dry" method



1 - bin, *2* – precipitation tank, *3* – collector of normal sodium solution, *4* – screw melter, *5* – sodium bin, *6* – air washer with barometer tube,
7 - cyclone, *8* - warmer, *9* – carbonizing column, *10* – precipitating tank,
11 - bag filter, *12* –centrifuge, *13* - elevator*, 14* – sizing seive,
15 – magnetic separator, *16* - heater, *17* – drum dryer, *18* - blower,
19 – overflow tank, *20* - pump

Sodium bicarbonate is dried by hot air injected to the dryer by the blower *18*, The air is heated in the heater *16* by the air steam and is cleaned from $NaHCO_3$ fractions by bag filter *11,* after which it is exhausted into atmosphere. For sizing particles of sodium bicarbonate shake-sieve *14* is used. Sodium bicarbonate divided into fractions passes through magnetic separator *15* and goes for packing.

During operating process the carbonizing column, whether "dry" or "wet" method is used, becomes gradually covered with sodium bicarbonate sludge. Hydrodynamic resistance starts growing, CO_2 concentration increases at the exit from the column, the quality of the crystals deteriorates, column production capacity falls. Therefore after 12-18 days of non-stop work a washer is installed on the carbonizing column. If there is another column in the workshop the output production is stopped, the column is discharged, terminating the delivery of liquid and gas, then the column is washed first by weak liquid, and then by water. Along with the liquid direct steam is delivered to the column, which allows to keep the liquid at 85-90 °C during its circulation through the column.