"Shenango No. 1," which ran between Conneaut and Canadian ports.

The wind has a great deal to do with the ice conditions, often piling the ice up mountains high in the ferries' path. In such cases, if an opening can be found in the windrows, the ferry may break through. Otherwise, dynamiting is sometimes done with good effect.

THE BATTLESHIP OF THE FUTURE.—II.

BY FORREST E. CARDULLO.

(Continued from page 133.)

In the case of large guns, the most effective caliber of weapon is the minimum caliber which will give the requisite penetration at probable battle ranges. The greater the weight of a gun, the less the number of hits which it will score in a given time. The greater the weight of a gun, the less the number of them which can be carried on a given displacement. Two shells of 1,000 pounds weight each will have more destructive effect than will one shell of 2,000 pounds weight, provided that they have sufficient penetrative power. From these several considerations, it becomes apparent that a large number of guns of sufficient caliber are much to be preferred to a smaller number of larger guns.

There is reason to believe, however, that the weights of projectiles of given calibers will be increased. If a number of projectiles of different weights be fired from the same gun with the same powder charge, all will have the same muzzle energy. The lighter ones will have the higher initial velocity, the greater penetrating power, and will experience the greater air resistance. On account of this resistance, the velocity, the striking energy, and the penetrating power of the lighter projectiles will fall off much more rapidly than is the case with the heavier projectiles, so that at the longer ranges, the advantage lies entirely with the latter. Let us take for example a 12-inch gun firing 800, 1,000, 1,200, and 1,400-pound projectiles, as shown in Table I. At the muzzle, and at 3,000 yards range, the lighter projectiles have the higher velocities, and the greater penetrations. At a little less than 6,000 yards range, all the projectiles have practically the same penetration, but the lighter ones are preferable, since they give the flatter trajectory, and will also score more hits for a given weight of ammunition carried. At 9,000 and at 12,000 yards range, it may be seen that the 1,000-pound or the 1,200-pound projectile is preferable, the greater penetration of the latter being offset by the flatter trajectory of the former.

TABLE I.

Length of gun, 50 calibers. Powder pressure, 21 tons per sq. inch.

Range, yds.			Zero.		3,000		6,000		9,000		12,000	
C.	G.	S.	V.	P.	V.	P.	V.	P.	V.	P.	V.	P.
12	65	800	3600	33.6	3030	25.8	2520	20 0	2060	14.6	1670	11.0
12	65	1000	3220	31.6	2790	25.2	2390	21.0	2030	15.2	1720	12.6
12	65	1200	2940	30.0	2600	25.0	2280	21.0	1990	16.7	1730	13.8
12	65	1400	2720	29.0	2440	24.5	2180	21.0	1940	17.4	1720	14.5

TABLE II.

Length of gun, 60 calibers. Powder pressure, 17 tons per sq. inch.

8	23	300	3160	19.5	2540	14.4	2010	10.4	1560	77.2	1222	5.3
10	45	580	3160	25 5	2670	20.0	2230	15.0	1840	11.5	1510	9.0
12	78	1000	3160	30.5	2730	24.6	2340	19.0	1990	15.6	1680	12.0
14	124	1600	3160	35.6	2790	29.5	2460	24.5	2150	19 0	1870	16.3
16	185	2400	3160	41.0	2840	35.6	2540	26.6	2260	24.8	2010	20.8

Length of gun, 50 calibers. Powder pressure, 27 tons per sq. inch.

8	23	350	3300	24 0	2760	18.4	2260	13.6	1830	10.0	1480	7.2
10	45	700	3300	30.0	2860	24.2	2460	19.3	2100	15 2	1780	11.9
12	78	1200	3300	36.0	2940	30 0	2590	25.2	2280	20.4	1990	17.0
14	124	1900	3300	42.0	2980	36.0	2680	30.7	2400	26.0	2140	22.0

In these tables C represents the caliber of the gun in inches, G the weight of the gun in tons, S the weight of the shot in pounds, and V and P the velocity in foot seconds, and the penetration of Krupp armor in inches respectively at the range given.

A comparison for all the ranges shows that the 1,200-pound shot gives the best average results, and is the one that should probably be adopted for this particular caliber and muzzle energy. For a greater muzzle energy, both the weight of the shot and the muzzle velocity should be increased, if we are to secure the most effective service from the gun. It may be stated as a general rule that the weight of projectile should be so adjusted to the caliber and power of the gun that the remaining velocity at the longest probable battle range shall be a maximum. This principle will necessitate an increase of from 20 per cent to 40 per cent in the weights of projectiles of given calibers.

Table II. gives the ballistics of two series of guns such as we may expect to see on the battleship of the future. An inspection of this table develops the fact that a 14-inch gun is probably as large as will ever be mounted on shipboard. The 16-inch gun weighs 50 per cent more than the 14-inch gun. Twelve 14-inch guns would be more effective than eight 16-inch guns, since they would fire twice as many aimed shots per minute, each of which is practically as effective as one from the larger gun. Both shells will penetrate any armor likely to be afloat for some time to come, at 9,000 yards range. The 16-inch shell has the advantage when employed against very heavy armor at more than 9,000 yards range, but this is not sufficient to counterbalance the advantages of the 14-inch shell at more practical ranges. Whether or not the 14-inch gun shall establish itself as the standard primary weapon is not clear from the table. The use of vanadium, or possibly some as yet undiscovered element, in the manufacture of armor may confer upon it such resistant qualities as to make the adoption of a 14-inch gun advisable, or changes in the propelling machinery may make the adoption of much thicker armor possible, but if neither of these possible events comes to pass, it is probable that the 12-inch gun will remain the most powerful naval weapon.

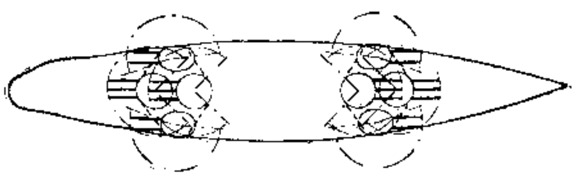

Fig. 7.—Twenty 12-Inch Gun Battleship. Two Groups, Each Containing Two 3-Gun and Two 2-Gun Turrets.

The proportion of weight which the modern designer devotes to armor is about 25 per cent. On the battleship "Connecticut" this gives us the equivalent of 12-inch armor over the vital parts of the ship. If the proportion of weight and distribution of armor remains the same, the thickness of the armor will vary as the cube root of the displacement. We should therefore expect a 20,000-ton ship to have 13 inches of armor, a 25,000-ton ship 14 inches of armor, and a 30,000-ton ship 14¾ inches of armor. None of this would be safe against guns of 10-inch caliber or over, at 6,000 yards, and the tendency will be to thicken it when possible. This may be done either by increasing the proportion of weight devoted to armor, or by reducing the area of the thin armor covering the non-vital upper works. The last method is far the best. If we increase the proportion of weight devoted to armor, it must be done at the expense of gun power. Any armor that can be made can be penetrated at some range, and our heavily armored ship may be attacked by a ship of thinner armor and superior gun power, and destroyed at short range where its superior armor is useless. At the same time, armor is necessary, for if a ship be unarmored, it would be quickly destroyed at long range by an armored vessel, while its own guns were powerless to inflict damage. There is a golden mean in the matter of the thickness and extent of armor carried, which will give the most powerful ship for the given displacement, and it will probably be found somewhere about as indicated in Table III.

TABLE III.

Displacement, Tons.	Armor Thickness, Inches.	Speed, Knots.	Displacement, Tons.	Armor Thickness, Inches.	Speed, Knots.
12,000	12.7	18.0	30,000	17 2	20.0
16,000	14.0	18.6	35,000	18.2	20.4
20,000	15.1	19.1	40,000	19.0	20.8
25,000	16.3	19.6			

In arranging the distribution of armor, the principle to be observed is to protect all of those parts of the ship whose integrity is essential to her fighting power, by armor of the greatest practicable thickness, giving all these parts substantially equal protection. The center of the ship constitutes a steel-walled fortress within which are assembled the boilers, engines, magazines, and other vital machinery and stores. In Fig. 8 are shown the midship and longitudinal sections of the ship shown in plan in Fig. 7. It will be seen that the walls of vertical armor constituting this fortress are about 12 inches thick above the water line, and taper to perhaps 9 inches thick at the lower edge, some six or eight feet below this. Meeting this lower edge is a sloping deck from 2½ inches to 4 inches thick, which becomes horizontal when it has risen to the same vertical height as the top of the armor belt. The end walls of the fortress, which are known as the armored bulkheads, are of about the same thickness as the side walls, but are protected by the armored deck, instead of protecting it. Thus any shot entering this central fortress must first penetrate two thicknesses of steel, one or both of which it must strike obliquely. If the projectile be a shell, the first thickness of armor will explode it, and the second thickness will effectually prevent the pieces from entering any vital spaces. The only projectile which can penetrate will be the comparatively harmless solid shot.

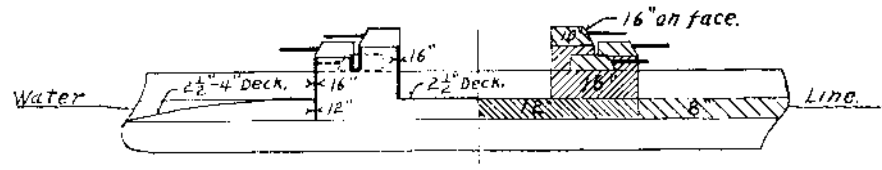

Fig. 8.—Longitudinal Section Showing Disposition of Armor.

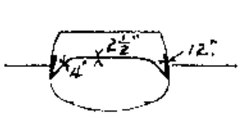

Fig. 8a.—Midship Section Showing Relation of Protective Deck to Belt Armor.

THE BATTLESHIP OF THE FUTURE.—II.

From the armored roof of this fortress rise the barbettes or citadels which form the supports for the gun turrets. The thickness of the armor inclosing these supports, and the ammunition hoists and gun mountings contained in them, will be about 16 inches in the case of the ship we are considering. The armor on the faces of the turrets will be of about the same thickness, while the sides and backs, being in general turned away from the enemy, will be thinner.

The entire water line of the vessel should be protected by armor of sufficient thickness to prevent the entrance of "common shell," a type of projectile carrying a very heavy and destructive bursting charge. This belt will have to be 8 inches thick if it is to oppose 14-inch guns, since common shell will pierce half its caliber of armor. There are a few other parts of the ship which it may be advisable to protect from shell fire, but in general the same principle holds in the case of armor as with guns, namely, that all armor should have the same resistance to penetration, just as all the guns should have the same penetrating power.

Besides the rifled gun, the only practical weapon of offense known to naval warfare is the torpedo. If two fleets of equal cost engage each other, the fleet of smaller and more numerous vessels will have the advantage in torpedo warfare. It will, however, be at a disadvantage with respect to gun power, armor, speed, and coal endurance. Since the vast majority of naval battles are decided by gun fire, the advantage will in general lie with the larger ships, but the possibilities of torpedo warfare will always act to prevent a further increase in the size of ships, if there is any doubt that the increase in size will confer a more than proportionate increase in power and efficiency. It is entirely possible that sufficient improvement may be made in the design and operation of torpedoes to throw a very decided advantage on the side of the smaller and more numerous ships, in which case the tonnages of the present may be adhered to for the future, or even reduced. This is a matter which can only be decided by pushing to the limit the development of torpedoes.

To have such an effect on the size of our future battleships, a torpedo must be designed with an effective range nearly equal to the effective range of the guns carried. It is not sufficient that the torpedo should run merely the distance indicated, but its speed and accuracy must be such that there shall be a reasonable percentage of hits, and its power must be sufficient to inflict a great deal of damage. Mechanically, it is possible to construct a torpedo of sufficient range and power, but the chances of a hit are very slim, unless used against a disabled ship, or a large fleet maneuvering in certain formations. We may construct a torpedo two feet in diameter and twenty feet long to carry 500 pounds of high explosive at a speed of 50 knots or more, and to execute any assigned course over a given area. If the course of a distant hostile fleet could be predicted for say eight or ten minutes ahead, it would be possible to have fifty or one hundred of these terrible engines of destruction continually circling in the waters over which the fleet would pass. Such a development of torpedo warfare would certainly affect naval tactics, and probably, battleship design.

No protection that we know of at the present time will avail against the torpedo if the size and cost of that weapon be sufficiently increased. To repel the attacks of torpedo boats, a battleship must be armed with a battery of from twelve to twenty guns of small caliber. It is evident that the effective range of these guns must exceed the effective range of the torpedo, that the caliber of the shell must be sufficient to destroy the torpedo boat before it has launched its bolt, and that the rate of fire must be very high. To obtain the requisite range and stopping power, a 5-inch gun is necessary, and to obtain a sufficient rapidity of fire to make such a defense effective against a simultaneous attack by several boats, the operation of the gun should be as nearly as possible automatic. Such a gun would require a large supply of ammunition, and powerful ammunition hoists, on account of the rapidity of fire. A battery of such guns would perform many of the functions in battle for which the secondary battery was originally designed, the most important being the attack of unarmored and lightly armored vessels, such as scouts, cruisers, and destroyers.

The speed of battleships will probably be subject to less variation than any other characteristic in the future. The speed of modern types of hulls may be represented very accurately by the formula

$$S = 6.35 \sqrt[3]{H.P. \div D^{\frac{2}{3}}}$$

where S is the speed in knots, $H.P.$ is the horse-power of the engines, and D is the displacement in tons. Designers seem at present to be of the opinion that the best results are obtained in the matter of all-around fighting efficiency by allowing 1 horse-power for each ton of displacement. This gives for various sizes of ships the speeds noted in Table IV.

The speeds may be made somewhat higher than this by increasing the engine power at the expense of armor, guns, economy, and cruising radius. It is not likely that they will exceed the speeds given by more than a few per cent, since these speeds, particularly for the larger ships, are amply sufficient for all strategic purposes. Tactically, additional speed confers no advantage that is not had more cheaply from heavier armor and armament. Of course the faster ship may theoretically choose her position and range, but if she is overmatched in guns and armor at all ranges, her only choice is to run.

We may therefore conclude that the speed of the battleship of the future will be kept down to the neighborhood of 20 knots, unless some radical change is introduced in her propelling machinery which will both lighten it tremendously and add at the same time to its efficiency. As a practical illustration of the cost of speed, let us take the case of one of the above-mentioned vessels, having 20,000 tons displacement, and 19.1 knots speed, and give it a speed of 24 knots. To do this, we must take 2,000 tons from the weight of its armor and armament, giving a reduction of over 40 per cent in its fighting power. In addition, we have increased the cost of maintenance of the vessel by about 25 per cent, and diminished its economical cruising radius in the same proportion. Even if we regard the 25 per cent increase of speed as producing a vessel of 25 per cent greater efficiency for the same fighting power, which is very doubtful, a fleet of such 24-knot ships will have only 60 per cent of the fighting power of a fleet of 19-knot ships costing the same money. While for certain purposes it may be advisable to build a few such ships, they will be by no means the most powerful and effective ships for their cost, and they will be of real value only in exceptional service demanding great speed.

Other things being equal, the further that a ship can travel without replenishing her coal, the more desirable she is. The greatest distance that a ship can travel without replenishing her bunkers is known as the coal endurance, the cruising radius, or the radius of action of the ship. This quantity varies for similar vessels as the cube root of their displacements, and for different types of engines inversely as the coal consumed per horse-power-hour at economical cruising speeds. The radius of action of the battleship of the future therefore depends almost entirely on the type and economy of the motive power.

So far as we know at the present time, there are three types of prime motors available as the propelling engines of warships: namely, the reciprocating steam engine, the steam turbine, and the producer-gas engine. Each one of these types has its own peculiar advantages which fit it for some particular service. The steam turbine has the advantage of freedom from vibration and also of extreme mechanical simplicity. The steam engine gives the best control of the ship when maneuvering, a matter of very great importance in naval warfare. The gas engine is the best of the three from the standpoint of economy of fuel and maintenance. Comparing these motors one with the other we find as follows:

In the case of the steam engine compared with the steam turbine, we find that for equal efficiency at all powers, they are of practically equal weight, since we require three turbines, called the cruising turbine, the backing turbine, and the main turbine, to perform the same service ordinarily obtained from one reciprocating engine. In addition to the matters of mechanical simplicity and freedom from vibration, the turbine is set low in the ship, and so is more easily protected than the steam engine. The steam engine is cheaper in first cost, is more easily repaired when injured in battle, and the ability to maneuver readily conferred by its use is a matter of very great moment in fleet actions. We may therefore conclude that while the steam turbine may be a preferable equipment for high-speed passenger ships and torpedo boats, it does not possess any great advantage over the reciprocating steam engine when installed in a battleship.

Comparing a gas engine using producer gas made from ordinary steam coal, with the steam engine, we will find that the total weight for a given power is practically the same in each case. It is possible to balance the gas engine more perfectly than the steam engine, but it will give more vibration than the steam turbine. By the use of compressed air for starting and reversing, the gas engine becomes as easily controlled as the steam engine. The gas engine will be set lower in the ship than the steam engine, but not so low as the steam turbine. In all other points, the gas engine is far ahead of either of the other types of motors, as will appear from the following considerations:

The efficiency of the gas engine in the matter of fuel consumption is twice as great as that of either of the other motors. This doubles the radius of action without any increase in the size of ship, a matter of great importance. The cost of fuel while the ship is in operation is only half of that for a steam-driven ship. The cost of maintenance also is very much less, since the upkeep of the producers is only a fraction of that of the boilers necessary in a steam-driven ship. The gas engine produces no smoke, which reduces materially the chance of discovery by the enemy, while the clouds of smoke belched from the funnels of a steam-driven vessel make its discovery an easy matter. In time of battle these same clouds of smoke and flame escape through the shot holes in the funnels and entering the gun spaces of the ship make the guns almost untenable, a condition of affairs which would not obtain in the case of a ship driven by gas engines. Should a shell penetrate the boiler room of a steam-driven ship, the damage to life and material would be enormous, and hours or days would be necessary to repair it. Should a shell penetrate the producer room of a gas-powered ship, the damage would be slight, and easily repaired, since the producers would be under suction, not pressure. Lastly, the producer-gas engine offers the combination of an economical motor of reasonable weight using coal as a fuel for low powers; and liquid fuel, which can be stored indefinitely in the double bottom of the ship, can be quickly gasified to greatly augment the power in case of emergency. Take for example a ship of 20,000 tons displacement. Equipped with engines of 30,000 horse-power, and producers of 10,000 horse-power, such a boat would have an economical cruising speed of 15 knots, and a very large radius of action. Should occasion arise, the more expensive liquid fuel would be instantly available to develop the entire 30,000 horse-power, giving her a speed of 22 knots. The whole weight of the apparatus would not exceed that of a 20,000-horse-power steam plant, and the ship would lose none of her effectiveness as a fighting machine.

We may therefore expect that the battleship of the future will be driven by producer-gas engines. The change will be slow to come, on account of the reluctance of both naval officers and naval designers to undertake to install or use anything so novel. In the substitution of any new and untried piece of apparatus for an old and tried one, the tendency is always to minimize its virtues and magnify its faults. Conservatism is practised to a grievous fault in all engineering work, more particularly that of a military or naval character. The gas engine will for this reason be slow in finding its place in the navies of the world, in spite of its many advantages, although its eventual adoption is certain.

In determining the displacement necessary to carry a given armament with the best efficiency, we will be guided by the following principles: First, that the total weight of the gun structures, including turret, barbette, loading gear, etc., varies as the square of the caliber when similar guns are in question. Second, that when guns of the same caliber differ in length, the total weight varies as the square root of the length. Although these principles are approximations, they are nevertheless very nearly true. We will, then, have for our displacement the formula

$$D = K N C^2 \sqrt{L},$$

where D is the displacement in tons, N is the number of guns if mounted in separate two-gun turrets, C is the caliber of the guns in inches, L is the length of the guns in calibers, and K is a constant to be determined by reference to existing designs. Taking the case of the "Dreadnought," we have for the value of K very nearly 1.90, which value we will use.

TABLE IV.

Arr. Number.	Caliber Guns, Inches.	Number Guns.	Displacement.	Length.	Breadth.	Draft.	‡ Speed.	§ Cruising Radius.	Armor Thickness, Inches.	Cost.	‖ Fighting Power.	Fighting Efficiency.
1	12	8	15 500	425	76	26½	18.5	5,500	13.5	$7.200,000	153	99
†1	14	8	21,000	470	84	29¼	19.2	6,100	15 8	9,900,000	282	134
2	12	10	19,500	460	82	28¼	19 0	6,000	15.0	9 200,000	181	93
4	12	12	23,400	485	90	30¼	19.4	6,300	16.0	11 000,000	259	111
†4	14	12	32,000	540	100	33½	20.2	7,000	17.7	15,000 000	460	144
6	12	12	21,400	470	85	29½	19.2	6,100	15.2	10,000,000	266	124
†6	14	12	28 000	516	93	32¼	19.8	6,700	17.0	13,200,000	473	169
5	12	16	26,000	503	90	31½	19.7	6,500	16.4	12,200,000	308	119
*7	8	20	13,000	430	70	25	23.0	5,100	7.0	6,500,000	76*	59
*7	10	20	20,000	500	80	28¾	24.0	5,800	9.0	9,600,000	182*	91
7	12	20	29,000	525	94	32½	20.0	6,800	17.1	13,600,000	422	146
†7	14	20	39,000	580	104	36	20.8	7,500	19.0	18,300,000	750	192

* These two vessels are armored cruisers, not battleships.

† It will not prove advisable to build these vessels unless their armor shall be able to resist the attacks of the 12-inch gun at the longer ranges. Should the 12-inch gun be able to penetrate their armor, the efficiency given is too high, as is also the fighting power.

‡ For gas-powered ships the speed is three knots more.

§ For gas-powered ships the cruising radius is doubled.

‖ For gas-powered ships the fighting power and efficiency are each 25 per cent greater.

In Table IV. we have the tonnages of vessels carrying from eight to twenty guns of different calibers. The length, breadth, and draft there tabulated are found by multiplying the cube root of the displacement by coefficients found from existing ships. The speed and armor thickness have been taken from Table III. The cruising radius given is for steam power, and is found by the formula

$$R = 220 \sqrt[3]{D}$$

where R is the radius in knots and D is the displacement in tons. For gas-powered ships, the cruising radius would be twice the figure given, and the speed would be three knots higher. The cost given is that of the entire ship, armor and armament included, estimated at $470 per ton.

In the column headed "Fighting Power" will be found a factor representing for each ship the writer's idea of her fighting abilities. This is found by multiplying together the power of the arrangement in gun units, the cube of the gun caliber, the square of the cube root of the armor thickness, the speed, and the sixth root of the cruising radius. It is evident that the relative value of these various elements is very largely a matter of opinion. The writer has not ventured his own opinion in this matter, but has given instead the opinion of the majority of naval designers as expressed in their most successful designs. The fact that designers stop at 25 per cent of the displacement for armor protection, instead of increasing the proportion and so thickening the armor, shows their opinion of the value of a given thickness of armor as compared with any other thickness. The "Fighting Efficiency" given in the next column is the quotient found by dividing the fighting power by the displacement.

While forecasts of the future are always uncertain, and it is impossible to see how changed conditions will affect the design of battleships, it is nevertheless reasonable to assume that the increase in tonnage will go on at about the same rate as it has in days gone by. In general, the tonnage will be the maximum which the development of docks and harbor facilities will permit. These developments go on under the influence of unchanging economic law, and are not affected materially by new discoveries and inventions, unless indeed these discoveries and inventions are of such vital and far-reaching importance as to affect in unforeseeable ways all marine design, that of battleships included. We are therefore reasonably safe in predicting the size of future battleships for given epochs by the law of increase in past years. In 1875 the average tonnage of first-class battleships laid down by Great Britain was 9,500. In 1885 it was 11,000. In 1895 it was 14,500. In 1905 it was 18,000. The law of increase is roughly 25 per cent per decade. Assuming that the same rate of increase is to hold for the next thirty years, we will have in 1915 ships of 22,500 tons, in 1925 ships of 28,000 tons, and in 1935 ships of 35,000 tons.

The Death of Prof. Mendeleef.

Prof. Dimitri Ivanovitch Mendeleef, one of the greatest chemists in the world, died recently in St. Petersburg. He was born in Siberia in 1834, and when a young man went to St. Petersburg, where he received his education. In 1861 he became professor of chemistry in the Technological Institute in St. Petersburg and became famous, not only as a chemist and a teacher, but also as a geologist and philosopher. In a few years he succeeded to the chair of chemistry in the St. Petersburg University. His field of original research was wide, and in 1871 he foretold the existence and general properties of three new chemical elements now tabulated under the names of gallium, scandium, and germanium. He wrote many papers on chemical topics, and his book, "Principles of Chemistry," was reprinted in many languages. He received the Cowley gold medal at a meeting of the Royal Society in London last year.

Formaldehyde Useless as a Preventive of Frilling.

Photography states that the practice of adding a little solution of formaldehyde to a developer to prevent frilling is entirely without effect owing to the decomposition of the formaldehyde by the sodium sulphite which is a component part of practically all developers. This results in the liberation of sodium hydroxide and may cause fogging owing to an excess of alkali.