Explanations of the keel and bow positions can be made considering the phenomena associated with an internal explosion alone. The explosion destroyed the hull girder by removing the sides, rupturing the decks, and decreasing the spacing between inner and outer bottoms. The bow section was separated from the stern section, except where it was attached by the keel and adjacent bottom plating, mostly on the port side. The protective deck was broken by the explosion at frame 24. Most of the forward portion of this deck was folded upward and forward over the bow, carrying portions of the berth, main, and superstructure decks along. Another phase of destruction then followed as a result of the sinking motions of the bow and stern sections. The repositioning of the protective deck and other weights made the bow extremely unstable and it capsized onto its starboard side. Because of the shape of the rigid remaining portion of the bow and its top-heavy condition, the after end of the keel at about frame 17 was raised well above its normal position. This led to severe deformation of the keel and attached bottom at frames 21 and 17 and formed between them the vertical section of keel noted in both the 1898 and 1911 investigations. The stern section of the hull flooded through the explosion hole so that the intact afterpart of the ship inclined down by the bow. Since the extreme bow was probably already on the bottom, the sinking of the stern section bent the keel and bottom in the vicinity of frame 35 by pressing the ship's bottom between frames 35 and 21 against the harbor bottom and/or by hanging it at frame 21 from the capsized bow section. The precise sequence of events that occurred cannot be established without experiment or further study, but it seems clear that the general mechanism explaining the final gross condition of the forward section of the wreck does not involve an explosion external to the hull. The absence of an external explosion near frames 18-22, where the keel V occurred, is also apparent from other evidence. Thus the internal magazine explosion was not centered in the forward 6-inch magazine (A-6-M), such as it should have been had the external explosion taken place there. Also, the bottom plating in the vicinity of frames 18-22 does not show the rupture characteristic of an external burst.[8]

Remnants of Mine or Torpedo Casing

No remnants of a mine or torpedo casing were reported found. If a sizeable mine or torpedo had indeed exploded, some remnants of the casing would have existed. However, the lack of remnants cannot be taken as positive proof that a mine or torpedo was not employed. The pieces could have been buried in the mud and thus easily missed.

EYEWITNESS REPORTS OF EXPLOSION PHENOMENA

Eyewitness reports are usually not reliable evidence, especially concerning high-speed technical phenomena. How much stock the 1898 and 1911 investigations put in eyewitness reports is impossible to say. We do know that nearly every witness before the 1898 court of inquiry was asked to describe, in as much detail as possible, his impressions of the explosion phenomena. The court's conclusion that there were two explosions must have been based on eyewitness descriptions. The 1911 report accepted and restated this conclusion. Although not expressed directly, it appears that the 1898 report advanced the two-explosion conclusion with the idea that the first of these must have been an underwater explosion. The eyewitness reports are discussed in the following, since we believe that the available evidence does not support the theory of two explosions, nor that the first explosion (had there been two) was outside the ship.

Observations from Other Ships

The eyewitness reports of the explosion vary considerably in detail, as can be expected. Most people reported hearing a double explosion with people at the greatest distances indicating the greatest time difference in arrival of the different sounds. For example, the master of the ship Deva, Captain Teasdale, felt the first shock and ran on deck to hear the main explosion. His position was between one quarter and one-half mile from the Maine. At a half-mile, the travel time for an underwater shock is about half a second; and for an air blast two and one-half to three seconds. Captain Teasdale could probably have reached his deck in two to three seconds. Similar differences of arrival time can be accepted for other remote witnesses and fit present knowledge of explosion phenomena. The fact that two phases were heard by some people does not indicate that there were two explosions. The sensing of two shocks is more a function of where the observer was.[9]

No one seems to have been looking directly at the Maine at the instant of the explosion. No witness reported seeing any surface phenomena, spray dome or plume, which might have come from an underwater explosion, but, since the night was dark, this is not surprising. No witness gave a clear description of certain rather awe-inspiring phenomena which must have occurred, such as the inversion of the pilot house and conning tower or the movement of the forward 10-inch gun turret some distance off the starboard side of the ship. At least one witness said the bow sank immediately, but whether this was because he saw it sink, or just believed it must have, is impossible to tell. A great many of the observers made contradictory reports, or reported events that were not evidenced in the final condition of the hull.

The 1898 Spanish board of inquiry took up the question of fish kill in some detail. The question was barely touched upon in the American court of inquiry. The Spanish knew, as did the Americans no doubt, that an underwater explosion will kill fish that are within range. A bottom detonation of 500 pounds of high explosive would probably have caused free-swimming fish to surface within a radius of 250-300 yards of the ship. A 100-pound contact charge would have injured fish out to a radius of 200-250 yards. On the other hand, even a violent deflagration of the powder inside the ship's magazine might not harm the fish at a modest distance from the ship. The type of underwater pressure waves generated by slow-burning black or brown powder are relatively innocuous to fish, even when the explosions occur in the water. Dead fish were not noticed after the Maine explosion, although much other debris was found. The Spanish took this absence as evidence of the absence of an external explosion. However, such a conclusion cannot properly be drawn. The only thing that can be said is that either there was no external explosion, or there were no fish nearby, or there were no dead fish found. Underwater explosion tests have often been carried out in modern times with no fish kill resulting, simply because there were no fish within range. Thus the absence of dead fish is inconclusive evidence, one way or the other. Had the evidence been reversed, that is, if dead fish had been found at some distance from the explosion, then it could have been concluded that in all likelihood an underwater explosion had taken place.[10]

Initial Response of the Ship Observed by the People Aboard

The testimony of people aboard the Maine concerning their impressions of the initial sounds and the initial movements of the ship also varies considerably. In general, they seem to verify the motions which can be expected from an internal explosion. One of the clearest testimonies was that of Naval Cadet W. T. Cluverius, who was in his quarters (frame 57 on the extreme starboard side) at the time of the explosion. He said:

> (1) My first knowledge of anything occurring was a slight shock as if a 6-pounder gun had been fired somewhere about the deck.
>
> (2) After that a very great vibration in my room, which
>
> (3) was then followed by a very heavy shock, and
>
> (4) still continued vibration and rushing of water through the junior officer's mess room, and the sound as if something breaking up all the time.[11]

These observations appear to correspond to internal explosion phenomena. Thus observation (1) describes the structure-borne shock or sound wave from the explosion; observation (2) describes the structural vibrations transmitted from the dynamically loaded and failing structure near the explosion; observation (3) describes the shock transmitted from the blast-loaded structure nearer his position, which occurred later due to the time it takes for the blast wave to travel through the air; observation (4) describes the vibration motions and sounds arising from large structural pieces, e. g. decks, falling back on the remaining structure and from the sinking of the ship.

Cadet Cluverius' observations were amazingly perceptive. Other witnesses mentioned different phases of the shocks, but were less clear about it. Their observations do not contradict those to be expected for an internal burst, although one witness, Lieutenant G. F. M. Holman, stated that "It was precisely similar to many other submarine explosions I have heard, except that it was on a much larger scale." Although this witness had some prior experience with underwater explosions, he could hardly have had much experience with internal explosions. He could, therefore, not be expected to be able to distinguish between internal and external explosions. It was possible that the 1898 inquiry put too much stock in his words because of his experience with underwater explosions.[12]

None of the onboard witnesses described motions which unmistakably can be ascribed to an underbottom explosion. Unfortunately, this absence cannot be taken as positive proof that an underbottom explosion did not occur, for both technical reasons and because of the unreliability of witnesses in such matters. The phenomena occur very rapidly, and even trained observers, who know what to expect, have difficulty in discerning them. If, for example, a Latimer-Clark mine with a 500-pound charge, similar to the type later employed by the Spanish at the entrance to Havana Harbor, exploded on the bottom which was only ten feet below the ship's keel, at least some of the witnesses should have noticed a very pronounced upward shock motion almost together with the first sound. There is no report of such a motion, indicating that it is reasonably certain that a large bottom mine was not exploded. If, on the other hand, a contact mine had exploded against the ship, the response of the ship to the underwater shock wave would have been much reduced. This is because the explosion largely vents into the ship, thus reducing the shock in the water. The shock response is also reduced because the angle of attack of the shock wave is 90 degrees (i. e. parallel to the ship bottom) rather than more normal as for the bottom mine. The shock response discussed here is the immediate elastic structural response to the underwater shock wave. The longer duration large whipping motions which would occur for both a contact and bottom mine explosion, if the magazine did not explode, would most likely be eliminated or at least be greatly modified by the overpowering response to the magazine explosion.

In summary, witness reports concerning the initial sounds and ship motions confirm the magazine explosion. They also indicate that a bottom mine explosion in all likelihood did not occur, but they cannot provide positive proof that an underbottom contact explosion did or did not occur.

FEASIBILITY OF MAGAZINE IGNITION BY EXTERNAL BURST

How could an external explosion ignite the powder in the magazine? Direct technical data, empirical or otherwise, to determine without a doubt whether or not such an ignition method would work, are not available today. It is known that black and brown powders are sensitive to heat. They have an ignition temperature of about 280 degrees centigrade. Black powder is relatively bullet insensitive, since black powder magazines are not ordinarily required to be of bulletproof construction. Shock sensitivity tests, which have been carried out by dropping a weight on a small amount of explosive, have shown black powder to be slightly more sensitive than TNT and far less sensitive than such explosives as mercury fulminate (used for detonators) and dynamites. This still does not mean that ignition by shock can be ruled out. However, the likelihood thereof is small. This seems to be indicated also by the response of the other magazines. The fixed ammunition and powder tanks in the A-9-M and A-13-M magazines were exposed to shock, pressure, and hot gas from the explosion of the 6-inch reserve magazine (A-14-M). The forces were sufficient to destroy the powder tanks, yet many of them, probably most of them, did not explode. This would appear to indicate that the shock and heat from an underwater explosion which would be less severe than from the explosion of an adjacent magazine would not have been sufficient to cause a mass detonation of the powder cans in the A-14-M magazine. However, positive proof of this is not available. But taken together with the other factors, it makes an external initiation even less likely. If the magazine explosion was to be initiated from the outside, it would have had to be done with a contact burst of some size. Such a burst would have left evidence in the form of torn and mangled plating in the outer bottom. The absence of this evidence was discussed previously in the section on "Critical Bottom Damage." A bottom mine, which in the case of the Maine would have been about ten feet below the ship's bottom, is not believed to have been capable of igniting the magazine. No appreciable heat or hot fragments would be injected into the magazine from such a burst. The bottom structure would be violently pushed in, but at the same time the bottom structure would rupture, water would be injected into the magazine. With water in the magazine, there would be little or no possibility of a chain reaction to cause explosion of all the powder tanks, even if one or a few of them should get ignited from shock.[13]

Even if a magazine ignition was possible by means of an external burst, there would still remain considerable questions concerning the feasibility thereof because of the difficulties associated with placing the charge. Assuming that the charge was placed shortly before the explosion, it can be definitely stated that it is not easy to place a large mine surreptitiously under a well-guarded alert war vessel, even today. The records indicate that the Maine was reasonably well-guarded. Many of the pros, cons, and difficulties of mine placement have been discussed elsewhere. Either of two groups might have wanted to place a mine under the Maine, though no firm evidence of such intent has ever been produced and verified. If civilians had attempted it, they would have had to find the right people, the right equipment, and enough explosive to do the job. The problems of manufacturing a functional, watertight mine are much greater than those encountered in making a satchel-bomb, such as might be used by a terrorist gang. Waterproofing, placing, and firing a mine are not jobs for amateurs. During the Vietnam War, the Viet-Cong/North Vietnamese trained underwater sappers for six months or more depending on the type of target (bridges, ships, etc.) for which they were being trained. In the field as much as a month was spent studying a particular target. Several dry runs and inspections might be made before trying to explode a charge. Swimmers were not able to handle more than 200 pounds of an explosive device at one time, even in water. Larger charges were built up of pieces carried in over a period of time or by several swimmers. These men had waterproof high explosives and sophisticated electric firing equipment available. River current was used to help carry the material into place without vigorous swimming. If civilians were able to mine the Maine without blowing themselves up, they were either lucky or geniuses.

The Spanish harbor defense force at Havana was not well equipped for sapper type mining of the Maine, and more conventional mining would have been obvious to many spectators. The force detailed (after the war started) to mining the harbor and controlling the mines consisted of 39 officers and men. Most of these seem to have been crew for mine and cable laying boats; there were only two torpedomen and two gunners. It is believed that laying and arming the Latimer-Clark electrical bottom type mines (226-kilogram charge, probably guncotton) that were available, would have required the services of a launch and a number of men.[14]

The evidence available does not indicate that the Havana harbor was mined prior to the outbreak of hostilities. If it was, nevertheless, the following applies. As previously discussed, only a contact mine would have had some possibility of igniting the magazine. A bottom mine would not have done it. But chances are that a contact mine would have exploded against the side of the ship rather than under the bottom. The 6-inch reserve magazine was protected on its outboard side by a double-bottom and coal bunker, and magazine ignition through the coal bunker is extremely unlikely to have occurred. A contact mine below the ship would have required a moor of exactly the right length. Further, such a mine would most likely have detonated earlier in the *Maine*'s visit since the ship would have swung through that quadrant as the wind and tides shifted. Thus a military mine planted in the usual way is unlikely to have caused the *Maine* explosion.

POSSIBLE SOURCE OF EXPLOSION, IF NOT A MINE

Several alternate sources of initiation of the explosion on the Maine have been suggested: a bunker fire, crew sabotage, a small arms accident, a bomb planted by a visitor, etc. It is believed that a fire in bunker A-16 is the most probable of all sources of the initiation because (1) frequent bunker fires did occur on warships of that period; (2) the type of bituminous coal in the A-16 bunker was known to have caused fires by spontaneous combustion; (3) the coal had been in bunker A-16 since loading at Newport News, Virginia, about three months earlier; (4) the bulkhead between A-16 and A-14-M was a single thickness of metal, probably 1/4-inch thick; (5) tanks of both 6-inch brown powder and black saluting powder were stored right against the bulkhead or at least very close to the bulkhead; and (6) ventilation of the bunkers was natural through a vent pipe to the forward stack, which was not in use, thus perhaps making the ventilation insufficient to prevent a rise in bunker temperature.[15]

Navy Regulations stated that the bunkers shall be inspected by the engineering officer before 10:00 a.m. each day. On the New York in March of 1897, a bunker fire occurred only three and one-half hours after the last normal inspection. The coal had been loaded aboard only 14 days when the fire broke out. The Maine had the same brand of coal in bunker A-16 and it had been on board three months. The longer the coal remained in a bunker, the more susceptable it was to spontaneous combustion. The explosion on the Maine occurred nearly 12 hours after the last required inspection time. This would indicate ample time, regardless of the inspection, for the initiation of a bunker fire, heating of the bulkhead, transmission of the heat to nearby powder tanks, and deflagration of the powder. [16]

It is evident that the storage of coal was hazardous. In the years between 1894 and 1908, more than 20 coal bunker fires were reported on U.S. naval ships. From the fact that extra bulkheads were ordered installed in the New York and new ships had double bulkheads surrounding their coal bunkers, it is evident that a number of people in the U.S. Navy did not believe that the system on the Maine was safe. [17]

SUMMARY

1. On the basis of witness testimony, the 1898 court of inquiry found that two explosions took place. This is likely an erroneous conclusion from the evidence. The sounds heard can be explained from the phenomena expected from a single explosion. If an external contact burst did take place, it would have been indistinguishable from the magazine explosion closely following. Thus there is no evidence from the sounds whether an external burst took place or not.

2. Witness reports concerning the initial ship motions at the instant of the explosion precludes a large bottom mine attack, but they are inconclusive concerning a contact mine attack. It is, in any case, not believed possible that a bottom mine could ignite the magazine.

3. The condition of the wreck as revealed in the photographs, drawings, and descriptions points toward the absence of an external burst, either contact or non-contact. The structural evidence erroneously interpreted in 1898 and 1911 as resulting from an external burst can be explained entirely satisfactorily as the result of an internal burst.

4. There is considerable doubt that an external burst of the magnitude associated with Spanish contact mines postulated for the 1898 period could, indeed, initiate a magazine mass detonation. Gunpowder is not shock sensitive to the same extent as some high explosives. Even the violent explosion of some of the magazine contents did not cause all of the powder tanks to explode, thus confirming the insensitivity of gunpowder in tanks to shock and transient heating. There is even more doubt that a small external burst could have done it.

5. The placing of a mine of sufficient size surreptitiously below the Maine would have been a very difficult undertaking. For this and other

reasons, the existence of such a mine is unlikely. Similarly, it is unlikely that a military mine placed in advance of the ship's arrival was the cause. A moored contact mine would most likely have exploded against the ship's side. This would not have ignited the critical magazine since it was protected along the side by a full coal bunker.

6. The recorded damage to the Maine is consistent with the effects to be expected from the explosion of up to 20,000 pounds of gunpowder in the forward magazines: including, specifically, most or all of the powder in the 6-inch reserve magazine.

CONCLUSION

We have found no technical evidence in the records examined that an external explosion initiated the destruction of the Maine. The available evidence is consistent with an internal explosion alone. We therefore conclude that an internal source was the cause of the explosion.

OPINION

It is our opinion that the Maine magazine explosion most likely was caused by heat from a fire in the coal bunker adjacent to the 6-inch reserve magazine. However, since there is no way of proving this, other internal causes cannot be eliminated as possibilities.

SIGNED: 30 April 1975

Ib S. Hansen
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NOTES FOR APPENDIX A

1. The records which Mr. Hansen and Mr. Price examined during the preparation of this analysis included: U. S. Congress, Senate, Message from the President of the United States Transmitting the Report of the Naval Court of Inquiry Upon the Destruction of the United States Battleship Maine in Havana Harbor, February 15, 1898, Together with the Testimony Taken Before the Court, 55th Congress, 2d session, 1898, Document 207 (as before, hereafter cited as Court of Inquiry); U. S. Congress, Senate, Report of the Spanish Naval Board of Inquiry As to the Cause of the Destruction of the U. S. B. S. Maine, 55th Congress, 2d session, 1898, Report 885; U. S. Congress, House of Representatives, Report on the Wreck of the Maine, 62nd Congress, 2d session, 1911, Document 310 (hereafter cited as 1911 Board) coupled with Naval Constructor Ferguson's reports from Havana in 1911 found in RG. 38, E. 242, Binder 108, NA and the Navy Department file on the Vreeland Board: RG. 80, E. 19, File 6658, NA (hereafter cited as Vreeland Board File). Also examined were ship's plans of the Maine (old): 103-6-12 "Berth Deck, 1897": 103-3-41 "Transverse Bulkheads, 1887": 103-3-43 "Hold and Magazines, 1887": 103-6-7 "Hold Plan, 1897": 103-3-40 "Expansion Plan of Outside Plating, 1887": 103-3-49 "Longitudinal Elevation, 1887": 103-3-49 "Main Deck Plating and Framing,

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1887": 103-3-42 "Inboard Logitudinal Elevation": 1-9-22 "Platform Deck Plating and Framing, 1887 with 1892 Notations": 103-3-32 "Platform Deck": 103-3-46 "Sheer, Half Breadth, and Body Plan, 1887": 103-6-14 "Superstructure Deck." All plans within RG. 19, E. 126, NA.

2. Photographs and drawings of the wreckage are in Ferguson's reports: RG. 38, E. 242, Binder 108, NA. The exhibits which accompanied the report of the Vreeland Board of Inspection and Survey in 1911 were never published but most may be found in the Vreeland Board File.

3. For a description of unexploded debris, see: 1911 Board, paragraphs 36 and 43 (pp. 10-11). Contents of the magazines were computed from Sigsbee to Commandant, Navy-Yard and Station, June 30, 1897 reproduced as Exhibit "G" in Court of Inquiry, pp. 292-293, "Table of Elements for Naval Guns, 1886" on page 47 in J. F. Meigs and R. R. Ingersoll, Text-Book of Ordnance and Gunnery (Annapolis: U. S. Naval Institute, 1887), and Chief of the Bureau of Ordnance to Board of Inspection and Survey, May 1, 1911, in RG. 38, E. 242, Binder 108, NA. For the extent of damage, see: 1911 Board, paragraph 26 (p. 8).

4. The appearance of the wrecked bottom structure on the port side between frames 22 and 23 is described in 1911 Board, paragraphs 30-35 (pp. 9-10). Bottom section 1 is described in paragraph 31 and sections 2, 3, and 4 are within paragraphs 33, 34, and 35. The low form of explosive theory is stated in paragraph 43 (p. 11) of the 1911 Board.

5. The smoothness of the inward folded section 1 is demonstrated in Vreeland Board File, Exhibits D-1, 2, and 3. For descriptions of typical Spanish mines of the 1898 period, see: M. Pluddemann, "Main Features of the Spanish American War," War Note 2, p. 12, in Spanish American War Notes 1-8, Office of Naval Intelligence (Washington: Government Printing Office, 1898); French E. Chadwick, The Relations of the United States and Spain. The Spanish American War 1 (New York: Charles Scribner's Sons, 1911), p. 80. The Navy Memorial Museum at the Washington Navy Yard has a Spanish mine reported removed from Havana Harbor in 1899. That the inner bottom was more mangled than the outer bottom may be seen in Exhibit D-1 in the Vreeland Board File.

6. The shape of the longitudinal web, frames 24 to 30, is seen in Exhibit D-1, Vreeland Board File.

7. The reference to the inverted "V" shape is in Court of Inquiry, p. 281. The point of the explosion is later located at frame 27 in 1911 Board, paragraph 37 (p. 10).

8. The destruction of the hull girder is evidenced by the inner bottom shown draped over the vertical keel in Exhibits D-6 and D-7 of the Vreeland Board File. The movement of the protective deck, carrying with it parts of the berth, main, and superstructure decks is seen in Exhibit C-3 of the Vreeland Board File.

9. Captain Teasdale's description is in Court of Inquiry, p. 53.

10. Two articles which concern the effects of underwater explosions upon fish are: Ermine A. Christian, "The Effects of Underwater Explosions on Swimbladder Fish," Naval Ordnance Laboratory Technical Report number 73-103, July 1973, and Carl L. Hubbs and Andreas B. Rechnitzer, "Report on Experiments Designed to Determine Effects of Underwater Explosions on Fish Life," in California Fish and Game 38 (July 1952): 333-366.

11. Cluverius' statements are in Court of Inquiry, p. 30.

12. Holman's testimony is in Court of Inquiry, p. 22.

13. The sensitivity of black powder is discussed in: Blasters Handbook (Wilmington, Delaware: E. I. DuPont de Nemours & Co., 1953). A comprehensive and technical description of the manufacture, grading, storage, and handling of ammunition such as the type used aboard the Maine may be found in: Description of Ammunition Used in the Naval Service and Instructions for Preparing Same for Issue. U. S. Navy, Bureau of Ordnance (Newport, Rhode Island: Naval Torpedo Station Print., 1896).

14. The difficulties of mining the Maine were recognized early. See, for example: J. T. Bucknill, "The Destruction of the Battleship 'Maine'," Engineering 65 (May 27, 1898): 650-651. The complexity of Spanish mine laying was observed by Americans during the war. See: Record of Proceedings of a Court of Inquiry in the Case of Rear-Admiral Winfield S. Schley, U.S. Navy (Washington: Government Printing Office, 1902), Volume 1, p. 934; Volume 2, pp. 1350, 1441, 1458. The mining of Havana Harbor during the war is described in Severo Gomez Nunez, The Spanish American War 3 (Madrid: N. P., 1900), Chapter 3.

15. Sigsbee testified before the Senate Committee on Foreign Relations on March 31, 1898 and stated that coal bunker A-16 contained New River brand bituminous coal taken on in Newport News three months prior to the

explosion: U. S. Congress, Senate, _Report of the Committee on Foreign Relations, United States Senate, Relative to Affairs in Cuba_, 55th Congress, 2d session, April 13, 1898, Senate Report 885, p. 489. Specifically, New River brand coal caused bunker fires on the _New York_ in March of 1897 and the _Brooklyn_ in May of 1898. See F. J. Schell, C. F. Snow, and C. Laird to Commanding Officer, USS _New York_ and attachments, March 11, 1897 and W. S. Schley to Secretary of the Navy, May 12, 1898, both in RG. 45, E. 464, File HF, _NA._ The chemical properties of this brand of coal were analyzed at the Washington Navy Yard in 1898. See: _Reports of the Efficiency of Various Coals 1896 to 1898, Expenses of Equipment Abroad 1902-1903, Recent Analyses of Coal at Navy-Yard, Washington, D.C._ (Washington: Government Printing Office, 1906). The stowage of powder close to the bulkheads is documented in ship's plan 158-7-3 "Stowage of Ammunition" in RG. 19, E. 126, _NA_ and from testimony given in _Court of Inquiry_, pp. 143-144. The method of ventilating coal bunkers is detailed in plan 103-7-5 "Ventilating System," RG. 19, E. 126, _NA._

16. Regulations regarding the inspection of coal bunkers are found in _Regulations for the Government of the Navy of the United States, 1896_ (Washington: Government Printing Office, 1896), p. 145. A detailed

description of the discovery and characteristics of a bunker fire is in W. S. Schley to Commander-in-Chief, North Atlantic Squadron and enclosures, March 11, 1897, RG. 45, E. 464, File HF, NA.

17. The retrofitting of extra bulkheads on the New York and recognition of the unsafe design of the bunkers and magazines on ships like the Maine was in a report submitted by the Board to Investigate the Spontaneous Ignition of Coal to the Secretary of the Navy. It was dated January 27, 1898—less than three weeks before the Maine explosion. The report was published in 1906 in Reports of the Efficiency of Various Coals. . ., pp. 81-85. James Webb, in his "Ventilation of Merchant Ships" appearing in Transactions of the Institution of Naval Architects 25 (1884): 276-284, estimated that between the years 1871 and 1881, 231 British merchant or warships were lost due to coal gas or spontaneous combustion. Numerous accounts of bunker fires may be found in RG. 45, E. 464, File HF, NA.