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REPORT No. 7

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FUEL RESEARCH INSTITUTE

OF SOUTH AFRICA.

BRANDSTOF-NAVORSINGS-INSTITUUT

VAN SUID-AFRIKA.

SUBJECT:
ONDERWERP: SPONTANEOUS COMBUSTION AND VENTILATION ON BOARD SHIP.

DIVISION:
AFDELING: CHEMISTRY

NAME OF OFFICER:
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FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

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SPONTANEOUS COMBUSTION AND VENTILATION ON BOARD SHIP.

It is well known that a heap of coal will not heat spontaneously if an air current of sufficient strength is passed through it. Under such conditions of over-ventilation the air cools any coal that may become heated. Generally each hold contains four ventilators. The air passes down two of these ventilators and up the remaining two. The down-draught ventilators stop at a height such that there is still a considerable amount of coal below the ventilator exit. The straight line connecting intake and offtake ventilators on one side of a hold passes outside the hatchway. There is generally a cone of fine coal in the centre of the hold i.e. vertically below the hatchway. This is surrounded by larger coal which presents less resistance to the flow of air. With the above arrangements it is practically impossible to produce over ventilation in fine coal vertically below the hatchway.

An alternative method of suppressing self-heating is to restrict ventilation or stop it entirely. The fact that a fair number of fires have recently occurred in ships carrying Natal cargo coal shows conclusively that over ventilation was not sufficient and that under ventilation was also not sufficient. It has been shown by the Fuel Research Institute that when air passes through certain Natal round coals at a linear velocity of about one foot per hour, considerable heating can occur. This is a very low rate of ventilation. It is clear that with the present method of ventilating coal cargoes the above rate of ventilation will exist in certain parts of the hold. It was therefore felt desirable to carry out tests on board ship in order to study the effect of ventilation on spontaneous heating. The Institute is indebted to the Ministry of War Transport of the United Kingdom for making

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the S.S. "EMPIRE PORPOISE" available for these experiments. The matter has been arranged by Mr. Cannan, the Ministry's Chief Representative in the Union of South Africa, and Mr. Seadle, the Ministry's Regional Representative (in Durban). The Institute desires to express its appreciation to these gentlemen for their kind interest and useful collaboration. I also wish to express my thanks to Captain Davies of the S.S. "EMPIRE PORPOISE" and to his staff for the valuable assistance they offered and for doing everything to make the voyage pleasant.

The plan of the top deck or weather deck is shown in Fig. 1B. The hatchways are labelled 1, 2, 3, 4, 5 and 6. Thermometer tubes were inserted through the top deck and tween deck and were fixed to the lower deck or tank top. The tubes were made of steam piping of $\frac{3}{4}$" internal diameter. The tubes passed down vertically and their position relative to the hatchways are shown in Fig. 1A. Thus, around hatchway number 1, there is one tube near each corner. These tubes are indicated by .A, .C, .E and .G. Near the middle of each side of a hatchway there is also one tube. These tubes are indicated by +B, +D, +F and +H. Each tube projected 3" above the top deck. A hole was drilled through this deck, the tubes were inserted and then welded to the deck. The tubes were similarly welded to the tween deck. They extended to the floor of the lower deck where they fitted into blocks of wood screwed to the lower deck. The tubes were plugged at their lower ends. Fig. 1E shows diagrammatically the arrangement of a thermometer tube. Five thermometers were placed in each tube excepting tubes H and D in hold No. 6 which contained four thermometers each. The bulb of the lowest thermometer in any tube was 6 feet above the lower deck. In tubes H and D of hold No. 6 the lowest thermometer was 12 feet above the general level of the lower deck. This arrangement had to be made since the shaft tunnel (9ft. 3 ins. high) prevented the deepest thermometer in these tubes from being 6 feet above the lower deck level. In any given tube, the bulbs of successive thermometers were 6 feet apart. The thermometer bulbs

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were fairly heat-insulated by means of rubber pressure tubing. This will allow a thermometer to be withdrawn and the temperature read before any appreciable fall in temperature takes place. Maximum thermometers have proved unsuitable for such work. Thermometers are labelled, for example, "6C3". This means that in hold No. 6 (See Fig. 1A) the thermometer is in pipe C and it is the third thermometer from the top of the pipe.

Details of the positions of thermometer pipes and normal ventilators with reference to particular hatchways are given in Figs. 2, 3, 4, 5 and 6. Ventilators are indicated by circles. Two concentric circles indicate concentris ventilators. Such ventilators consist of a large pipe which generally stops immediately below the top deck. This pipe therefore ventilates the tween deck hold. The large pipe may, however, be sealed off at the top deck level. This is indicated in the figures by shading the area between the two concentric circles. In such a case, there is no ventilation of the tween deck hold from such a ventilator. In the case of concentric ventilators, the smaller ventilator stops immediately below the tween deck. It therefore ventilates the cargo hold. In many cases, to prevent direct impingement of air from the ventilator on to the cargo, a baffle is placed about 6 inches below the lower opening of the ventilator. This is indicated in the figures.

In the figures referred to, the position of each ventilator is noted by two sets of numbers. The upper numbers indicate the perpendicular distance between the centre of the ventilator and the side (or its extension) of the hatchway nearest to it, such side running parallel to the long axis of the ship. The lower numbers indicate the perpendicular distance between the centre of the ventilator and the side of the hatchway nearest to it, such side being at right angles to the long axis of the ship. In these figures, the hatchways are indicated by  and they are supposed to have shrunk infinitely small. The positions of thermometer tubes are also indicated by two sets of numbers. In the case of thermometer tubes marked by a dot, the upper numbers indicate the perpendicular

distance/...

distance between the tube and the side (or its extension) of the hatchway nearest to it, such side being parallel to the long axis of the ship. For thermometer tubes marked with a dot, the lower numbers indicate the perpendicular distance between the tube and the side of the hatchway nearest to it, such side being at right-angles to the long axis of the ship. In the case of thermometer tubes marked with a +, the upper numbers indicate the perpendicular distance between the tube and the side of the hatchway nearest to it. The lower numbers, in the cases of 1 + H, 1 + D, 3 + D, 3+H, 6 + H and 6 + D, indicate the perpendicular distance of the tube from a line running through the centre of the hatchway and parallel to the long axis of the ship. The lower numbers in the cases 1 + B, 1 + F, 2 + A, 2 + B, 5 + A, 5 + B, 6 + B and 6 + F, indicate the perpendicular distance between the tube and the line passing through the centre of the hatchway, such line passing at right-angles to the long axis of the ship (See Fig. 7).

The tween deck (floors) are shown in Fig. 1C. The hatchways in the tween deck (floors) are the same size as those above in the top deck, excepting that hatchway No. 4 in the top deck is represented by two smaller hatchways in the tween deck. The floors of the tween deck holds are shaded around the borders in Fig. 1C. It will be seen that in the tween decks, holds numbers 4 and 5 are not separate, although they are separated below in the cargo hold.

The cargo deck floors are shown in Fig. 1D, the areas occupied by the different holds being enclosed in shaded borders.

Owing to the diminution of the cross-section of the cargo deck at both ends of the ship, the thermometer pipes are much nearer the side of the ship in these areas than elsewhere. Table 1 gives the distance, in inches, between the thermometer tube and the side of the ship.

TABLE I.

Thermometer Tube.	At top and Tween deck.	At Cargo Deck.
1A	93	49
1B	126	79
1C	163	110
2A	191	187

Table I : Continued.

Thermometer Tube.	At Top and Tween Deck.	At Cargo Deck.
3A	185	184
3B	192	187
3C	188	183
3G	231	231
5A	191	190
6A	188	131
6B	184	53
6C	181	0

Holds numbers 1, 3 and 6 are primarily to be considered as the experimental holds for the purpose of this test. They were therefore each provided with eight thermometer tubes. During the test tween deck hold No. 1 and cargo hold No. 1 received what is considered to be normal ventilation. The hatch covers were battened down, but, weather permitting, the covers were lifted off on two sides of the hatchway as from 26/8/44. The ventilators were turned according to the direction of the wind. Tween deck hold No. 3 and cargo hold No. 3 also received normal ventilation, although it will be seen from Figs. 2 and 4 that the ventilators are not the same as regards baffle arrangements. Hatch covers of Nos. 6, 5, 4 and 2 were kept battened down and no ventilation was provided by lifting the hatch covers. In addition, all ventilators passing into tween deck holds and cargo holds of Nos. 6, 5, 4 amd 2 were sealed off. Cargo holds 1, 3 and 6 as well as the corresponding tween deck holds were filled with the following Natal coals: A, B, C and D. These coals have a reasonable temperature rise in the spontaneous ignition tests carried out by the Fuel Research Institute at the Bluff. Holds numbers 2, 4 and 5 were filled with other coal that was available. The quantities of the various coals loaded into each hold and the order in which the coals were loaded are given in Appendix A. The manner of loading is also indicated in this Appendix. Loading was carried out during dry weather and the coal was not wetted by rain.

Provision was also made to take gas samples above the surface of the coal in the various holds. These samples were withdrawn by tubes passing through the hatch coamings about 1

foot/.....

foot above the surface of the top deck. The tubes projected about 1 foot into the hatch. In tween deck holds No. 6, the upper level of the coal did not reach the position of the highest layer of thermometers. The tween deck hold was only covered with a few feet of coal above the tween deck hatchway, the sides containing no coal. In No. 1 tween deck hold the coal reached to above the highest layer of thermometers. The same applies to holds 2, 3, 4 and 5.

Loading of coal into No. 3 hold commenced at 3.45 p.m. on 16/8/44 and the loading of the ship was completed at 10.15 p.m. on 18/8/44. Hatch cover No. 3 was put on on 18/8/44. The remaining hatch covers were put on on 19/8/44. Ventilators were adjusted on 19/8/44, excepting that one ventilator in No. 6 hold was only sealed on 20/8/44. Thermometers were inserted on 19/8/44 and the first readings were taken on 20/8/44, commencing at 12.15 p.m.

The temperatures recorded in the various holds, the oxygen contents of the gases immediately below the hatchways, and the weather conditions are given in appendices B, C, D, E, F and G.

TEMPERATURES.

During the discharging of the coal temperature measurements were also taken in the coal in the areas vertically below the hatchways. In a few cases these temperatures were obtained by driving pipes of 6 feet length into the coal and inserting partly insulated thermometers. This procedure took a long time and seriously interfered with the discharging. The normal procedure was to stop discharging of a given hold and immediately drive a hole of about 1 foot deep into the coal by means of a pipe, withdraw the pipe and insert a bare thermometer into the hole. Such thermometers were spaced at a distance of approximately six feet from each other. The thermometers were withdrawn after about 10 minutes and read before any appreciable fall of temperature occurred. It was not possible to retain thermometers in the original thermometer tubes for any length of time after discharging had commenced. The discharging buckets frequently knocked against the thermometer tubes with the result that the latter became bent and the thermometers/....

ters were broken.

Such temperatures as were recorded in the thermometer tubes in holds 1 and 3, receiving normal ventilation, after discharging had commenced, show that between 7/9/44 and 10/9/44 no undue rise of temperature occurred.

If it be assumed that the same applies to the coal vertically below the hatchways then it follows that the temperatures below the hatchways were, in many places, higher than in the surrounding areas served by the thermometer tubes. The differences were appreciable. Thus the highest temperature recorded in a thermometer tube in No. 1 hold on 7/9/44 was 50.6°C, whereas the highest temperature recorded in the coal vertically below the hatchway on 11/9/44 was 90°C. In a horizontal plane these areas were about 15 feet apart.

Owing to the rapid rise of temperature found in hold No. 3, during the voyage, this hold was sealed on 30/8/44. After sealing the rate of rise of temperature decreased, but the rise of temperature and the percentage of oxygen were still high. This showed that this hold was still getting appreciable quantities of air. A storeroom with wooden walls had been built into the for'd part of this hold. The wood had shrunk considerably and it was clear that air could still pass into the coal through the openings in the wood. This was confirmed during discharging.

The lowest layer of thermometers was 6 feet above the cargo deck. For the purpose of discussion it is convenient to refer to the level of this layer as the 5th level. The next layer of thermometers was 12 feet above the cargo deck. This level is referred to as the 4th level. Similarly there are 3, 2, and 1.

Levels 1 and 2 will not be considered in any detail since it is clear that the temperatures at these levels were substantially influenced by weather conditions. Thus, when the weather became overcast there was a general tendency for the temperatures at these levels to drop. Also the temperatures at these levels, particularly in the normally ventilated holds, were generally lower than the temperatures at lower levels. Thermometer 1F1 is however a

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striking exception.

An examination of the recorded temperatures shows that the average temperature rises of all the thermometers in tubes in levels 5, 4, and 3 in holds nos. 1 and 3 were greater than in the sealed holds. See Table 2. The examination, however, also shows that large temperature rises in holds Nos. 1 and 3, at any given level, were obtained in certain areas only. This, together with the fact that a fire starting in one part of a hold may set all the coal on fire is the reason why average temperature rises are not dealt with in greater detail in this report.

TABLE 2.

AVERAGE RISE OF TEMPERATURE IN LEVELS 5, 4 AND 3.

Date	20-22	22-24	24-26	26-28	28-30	20-30 August.
Hold 1	1.76°C	1.70	1.18	0.85	1.28	6.8
3	2.06	1.50	1.74	1.78	1.56	8.6
6	1.49	0.58	0.63	0.67	0.64	4.0
2	0.68	0.42	0.26	0.45	0.52	2.3
5	0.75	0.35	0.53	0.65	0.78	3.1

Table 3 gives the four highest temperatures in each of holds 1, 3 and 6, at each of levels 5, 4 and 3 on 30/8/44, together with the corresponding temperatures on 20/8/44 and the rises of temperature.

Similarly Table 4 gives the four highest temperatures in each of holds 1, 3 and 6 at each of levels 5, 4 and 3, on 7/9/44, together with the corresponding temperatures on 30/8/44 and the rises of temperature. It will be remembered that hold No. 3 was partly sealed on 30/8/44.

Table 3/.....

TABLE 3.

LEVEL	NO. I. HIGHEST TEMPERATURE 30/8/44.	NO. I. Tempt. 20/8/44.	NO. I. Rise	NO. 3. HIGHEST TEMPERATURE 30/8/44	NO. 3. Tempt. 20/8/44	NO. 3. Rise	NO. 6. HIGHEST TEMPERATURE 30/8/44	NO. 6. Tempt. 20/8/44	NO. 6. Rise
5	39.8°C	27.0	12.8	40.5	27.2	13.3	26.2	24.0	2.2
	34.6	27.0	7.6	39.8	27.2	12.6	26.0	23.5	2.5
	33.7	26.0	7.7	39.4	26.5	12.9	25.6	23.0	2.6
	33.7	28.0	5.7	37.8	26.5	11.3	25.6	24.5	1.1
4	41.0	27.5	13.5	44.8	26.0	18.8	35.6 *	26.5	9.1
	39.7	29.4	10.3	41.3	26.0	15.3	35.4 *	25.5	9.9
	38.0	27.0	11.0	39.8	26.5	13.3	28.9	24.0	4.9
	35.5	27.5	8.0	39.5	26.5	13.0	28.0	23.0	5.0
3	39.7	28.0	11.5	36.6	26.5	10.1	32.5 *	26.0	6.5
	35.7	24.0	11.7	36.0	26.0	10.0	31.5	26.0	5.5
	34.8	24.0	10.8	35.2	25.5	9.7	30.5	25.0	5.5
	32.3	28.0	4.3	32.7	25.5	7.2	30.2	24.0	6.2

* Thermometer near steam pipes. The propeller shaft tunnel runs aft in the centre of the cargo deck of holds 5 and 6. Inside this tunnel, immediately below the coal, there are two steam pipes for operating the steering mechanism. The highest temperatures in Nos. 5 and 6 were recorded over this tunnel.

TABLE 4.

LEVEL	NO. 1. HIGHEST TEMPERATURE 7/9/44	NO. 1. TEMP. 30/8/44	NO. 1. RISE	NO. 3. HIGHEST TEMPERATURE 7/9/44	NO. 3. TEMPT. 30/8/44	NO. 3. RISE.	NO. 6. HIGHEST TEMPERATURE 7/9/44	NO. 6. TEMPT. 30/8/44	NO. 6. RISE.
5	46.0°C	39.8	6.2	45.5	39.4	6.1	28.2	26.0	2.2
	39.6	34.6	5.0	44.4	40.5	3.9	28.2	26.2	2.0
	38.4	33.7	4.7	44.3	39.8	4.5	28.0	25.6	2.4
	35.5	33.7	1.8	42.5	37.8	4.7	28.0	25.6	2.4
4	50.6	41.0	9.6	57.0	44.8	12.2	39.6 *	35.6	4.0
	43.3	39.7	3.6	50.0	41.3	8.7	38.0 *	35.4	2.6
	41.5	38.0	3.5	48.6	39.8	8.8	31.0	28.9	2.1
	39.9	34.4	5.5	45.7	39.5	6.2	30.3	28.0	2.3
3	44.1	35.7	8.4	43.7	36.0	7.7	36.3 *	32.5	3.8
	43.2	39.5	3.7	42.0	36.6	5.4	34.5	31.5	3.0
	40.3	34.8	5.5	41.5	35.2	6.3	33.7 *	30.2	3.5
	36.4	32.3	4.1	41.0	32.7	8.3	33.6	29.6	4.0

* Thermometer near steam pipes.

Table 5 gives the maximum temperature observed in each hold taken during the time coal was being discharged.

TABLE 5.

HOLD.	MAXIMUM TEMPERATURE.
1	90.0°C
3	64.0
6	41.0 *
2	36.0
5	43 *

* Thermometer near steam pipes.

It is clear from the data given in tables 2, 3, 4 and 5 that the average rise of temperature as well as the maximum rises of temperature and the maximum temperatures, at times stated, are greater in the ventilated holds than in the sealed holds, and that the differences between ventilated holds and sealed holds are substantial.

The following additional remarks are interesting in connection with the heating of the coal. During discharging it became apparent that coal vertically below the hatchway was generally of smaller size than the surrounding coal. This condition was undoubtedly caused by segregation during loading. From the relative positions of a hatchway and the ventilators of any hold, it is clear that the main ventilation currents will travel through the coarser coal. This together with the relatively small surface of coarse coal will tend to keep it comparatively cool. During loading, pockets of small coal as well as pockets of large coal are produced vertically below the hatchway. It is probable that these pockets are responsible for sufficient air entering the main masses of fine coal to produced the heating observed. The higher temperatures were always observed in holds 1 and 3 in masses of fine coal during the discharging. But even here some of the pockets of fine coal were comparatively cool compared to others close by. The result is that it is very difficult to locate the points of highest temperature in a ventila-

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ted hold with a limited number of thermometer pipes. I understand that coaling ships at present are provided with one thermometer tube, in the corner of a hatchway and that this tube stops slightly below the tweendeck. It will be fortunate indeed if any temperature taken in such a tube will give any warning of approaching danger from heated coal. If the above experiments had to be repeated with 8 thermometer tubes in each hold I would suggest that such tubes be placed in two parallel rows, parallel to the long axis of the ship, inside the hatchway and about 6 feet away from the coamings running in the same direction

The high rate of heating in No. 3 hold, until it was partly sealed off, needs consideration. The aft bulk-head of No. 3 receives radiant heat from the furnaces. It was thought that this heat may be responsible for the high rise of temperature. During the discharging on 11/9/44 the following temperatures were recorded vertically below the hatchway: 48, 48, 60,47, 45, 53, 44, 34. At the same time the following temperature readings were obtained, at the same level, in the coal in a line about 3 feet aft of thermometer tubes; 3C, 3D and 3E: 39, 38, 39, 40, 40. At this level the coal is therefore cooler near the bulkhead than further for'd. This suggests that the heating of the bulkhead was not entirely responsible for the rapid temperature rise in No. 3 hold. All the coal in No. 3 was loaded by the belt system and it was clear that the coal in the top part of this hold was smaller in size than in holds Nos. 1 and 6. In addition the ventilation in hold No. 3 could be considered as being better than in hold No. 1. This is due to the fact that the off-take ventilators in No. 3 hold were two Samson posts. These posts project about 20 feet above the top deck and will act as chimneys. It is also possible that the high temperatures observed in No. 3 may be in some measure associated with the greater distance of the thermometer tubes from the sides of the ship. See Table 1.

It is interesting to note that the highest temperature, namely 90°C, obtained during the discharging of No. 1, was found

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near its for'd part corner, i.e. in the area between thermometer pipes F. G. and H. See Fig. 1A. Temperatures of 80°C were registered just for'd of tube D. The highest temperatures obtained in No. 3 during discharging were in the area between thermometer pipes D, E and F.

OXYGEN CONTENT AND INFLAMMABILITY OF GAS IMMEDIATELY BELOW HATCH COVERS.

All apparatus for gas analysis had to be screened down in not too large a cabin and duplicate sets of apparatus had to be taken in case of breakage. This is the reason for the comparatively simple gas analyses that were carried out.

Each hatch was covered with three tarpaulins and the samples for analysis were taken about 1.5 feet below these. Such samples would be fairly representative of the gases above the coal. Unless a large number of samples were taken at various points inside the coal the results would be difficult to interpret. Oxygen and carbon dioxide were absorbed simultaneously in alkaline pyrogallol. The Institute, in spontaneous heating tests in bunkers, has shown that the percentage of carbon dioxide given off below 80°C is small. Hence oxygen and carbon dioxide are together given as oxygen in Appendix F. After absorption the gas was returned to the gas pipette and then allowed to escape into the atmosphere through a stop-cock under about 18 inches of water pressure. A lighted match was held in the path of the escaping gas. In no case would the gas ignite. Tarpaulins were placed over No. 3 hatchway on 18/8/44 and on the remaining hatchways on 19/8/44. On 26/8/44 the tarpaulins were lifted off the sides of Nos. 1 and 3 and this position was maintained in the case of No. 1 until discharging commenced. No. 3 was kept sealed from 30/8/44 until discharging commenced. The analyses show, in the cases of Nos. 1 and 3 that even prior to lifting the tarpaulins off the sides the gas consisted practically of pure air.

After sealing No. 3 on 30/8/44 the oxygen content fell to

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about 17%, and then remained in this neighbourhood. This, together with the fact that the temperature of this hold was still rising appreciably clearly showed that the sealing was inadequate. The gas above No. 6 consistently showed a low oxygen content, the average value being 7.2%. It is considered that this figure represents the balance between fresh supplies of oxygen obtained by diffusion through the tarpaulins and oxygen removed by the coal. The average oxygen contents of Nos. 2 and 5 were 13.0% and 15.7%, respectively. These data suggest that the coals in Nos. 2 and 5 were less active as far as spontaneous heating was concerned than the coals in No. 6.

The only fear that I had about these experiments was the possibility of fires and explosions from methane in the sealed holds. The gases immediately below the tarpaulins have been shown to be non-inflammable. It is clear therefore, that no fires can be started above the tarpaulins by striking matches, etc. The gases immediately below the tarpaulins undoubtedly contain a small percentage of methane, but this percentage is maintained small by loss into the air by means of diffusion. At depth in the coal this percentage of methane will increase. There is a possibility that such methane may escape through leaks in the bulkheads to neighbouring holds containing exposed fires and be there set on fire. This danger seems remote. Firstly, because the rate of methane evolution from freshly loaded coal becomes comparatively small after the first day. Secondly, a recent circular by the Ministry of War Transport supports the general practice, in case of coal fires at sea, of sealing off the effected hold. Once a fire has started in a hold the amount of inflammable gases produced by distillation and incomplete combustion will greatly exceed the normal methane evolution of the same coal when cold. The danger of fire and explosions is thus considerably increased. If it is considered good practice to seal off a hold that is on fire, it is surely better practice to seal it at the start and prevent a fire altogether.

WEATHER CONDITIONS.

The prevailing weather conditions during these tests are given in Appendix G. The air temperature, strength of wind and a clear or cloudy sky will all influence the coal temperatures in the holds. It is difficult to determine the separate effects when all these variables alter at the same time. The strength of the wind undoubtedly has a big effect upon the temperatures in the lower levels of the ventilated holds. Thus, with a mild wind there will be little over ventilation and there may be a fair amount of heating in the direct path of the ventilation current. On the other hand more distant parts will be under ventilated and remain cool. With a strong wind there will be considerable over ventilation in the direct path, but in the more distant parts the correct amount of ventilation may be produced to give rapid heating. It is no doubt partly the explanation of the variations of the temperature increments in the deeper levels of the ventilated holds during the course of the tests.

Cloudy weather seems to have a very important influence upon the temperatures in levels 1 and 2. It will be seen that the temperature increments at these levels during cloudy weather are generally small or negative. The rise of the sea temperature from 20.2°C to 26.6°C is interesting. At the higher temperature the loss of heat from the coal by conduction will be much less than if the sea had remained at the lower temperature.

CONCLUSIONS.

1. In hold No. 6, where the hatchway remained covered by three tarpaulins, and where the ventilators were sealed, the rise of temperature of the coal was substantially less than that experienced by the same coals in two holds receiving normal ventilation.

2. It is considered that the sealing of holds, as carried out in No. 6, will substantially decrease the danger of spontaneous combustion of coal.

3. The gas in the sealed hold, immediately below the tarpaulins

did not in these experiments contain sufficient combustible matter to enable it to burn in air.

4. It is considered that the danger of fires and explosions of gases derived and escaping from holds sealed shortly after loading the coal is considerably less than that arising from the standard practice of sealing such holds only after a fire has started.

5. In the normally ventilated holds the higher temperatures during discharging were found in pockets of fine coal. The temperatures in different pockets of fine coal in a given hold varied considerably.

6. The coal vertically below the hatchway, in the normally ventilated holds, was generally at a higher temperature than the surrounding coal, such temperatures being measured during discharging.

7. To determine the extent of spontaneous heating in holds temperatures ought to be taken, as described, at a number of points in the coal vertically below the hatchway. The present practice of having one thermometer tube against the corner of a hatchway and passing down to slightly below the tween deck may give entirely misleading results.

8. The temperature of approximately the upper 12 feet of coal in a hold was seriously affected by weather conditions.

9. In the normally ventilated holds the level of highest temperatures was approximately at 6 - 18 feet above the floor of the coal.

If Natal cargo coal is to be carried at sea in holds having all ventilators sealed and in which the three hatchway tarpaulins are kept battened down, it is considered advisable to make the following suggestions:

(a) The tarpaulins should be put on approximately 24 hours after the coal has been put into the hold and they should be removed approximately 24 hours before commencing the discharge of the coal. Ventilators should be sealed when the tarpaulins are put on and unsealed when the tarpaulins are removed.

(b) If any particular hold contains holes that cannot conveniently be sealed, such a hold should be filled with coal having a poor tendency to heat spontaneously. This hold should otherwise, as far as possible, be dealt with as in (a) above.

(c) Naked flames should not be brought within, say, 3 feet of the bulkheads of sealed holds.

(d) Holds or rooms, adjoining sealed holds carrying coal, should be very well ventilated, unless such holds carry coal and are themselves sealed.

SHIP DATA.

Built 1918, Alameda, California.

One deck and one shelter deck.

Gross: 7592 tons.

Net: 4847 tons

Length: 440 feet.

Breadth: 56 feet.

Depth: 35.2 feet.

Steamship fitted for oil fuel.

APPENDIX A.

Table I gives the kind of coal loaded into cargo and tween deck holds numbers 1, 3 and 6:

TABLE I.

Colliery:	Hold No.1.	Hold No.3.	Hold No.6.
A	233.15	-	221.10
B	172. 7	82.15	249.15
C	-	131. 5	162.15
A	230.15	173.15	167.10
D	45. 0	161.12	148.12
B	287. 0	269. 9	256. 0
C	225. 0	225. 5	232. 5
A	189.10	232. 5	244. 5
TOTAL	1376.14	1276. 6	1682.12

The coals were loaded into each hold in the order from below upwards. For example, in No. 1 hold, 189.10 tons of A were first put in. This was followed by 225.0 tons of C, etc.

Table II gives the total amounts of coal from each colliery put into holds 1, 3 and 6:

TABLE II.

Colliery:	Hold No. 1:	Hold No. 3:	Hold No. 6:
B	452.14	352.14	505.15
C	225. 0	356.10	395. 0
A	654. 0	406.0	633. 5
D	45.0	161.12	148.12

Table III gives the total amount of coal put into each of holds 2, 4 and 5 from each colliery. This coal was not loaded in any particular order:

Table III.

Colliery:	Hold No. 2:	Hold No.4.	Hold No.5:
B	-	-	34.15
E	915.13	262.17	776.17
F	390. 5	591.10	674.15
G	172.10	45.10	251.15
H	324. 5	35.15	194.15
TOTAL	1802.13	935.12	1932.17

It will be noted that except for 1 truck of B coal in Hold No. 5, none of the holds 2, 4 and 5 contain any of the coals in holds Nos. 1, 3 and 6.

The coal was loaded partly by the belt system and partly by the bucket system. Table IV. shows the means of loading. Where both belt and buckets were used in any one hold the belt was used first:

TABLE IV.

Hold:	Belt:	Bucket:	Total:
1	970.12	406. 2	1376.14
2	1354. 0	448.13	1802.13
3	1276. 6	--	1276. 6
4	760. 0	175.12	935.12
5	1792. 0	140.17	1932.17
6	1307. 7	376. 5	1682.12

S.S. EMPIRE PORPOISE

PLAN OF HATCHES AND THERMOMETER PIPES. DECKS.

THERMOMETER PIPES NEAR HATCH CORNER MARKED • WITH LETTER.

THERMOMETER PIPES NEAR MIDDLE OF TWO HATCH CORNERS MARKED + WITH LETTER.

FIG. 1A

TOP DECK

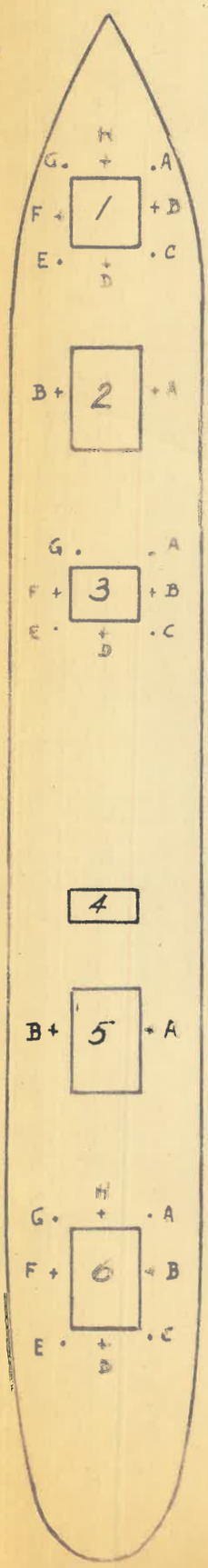


FIG. 1B

TOP DECK

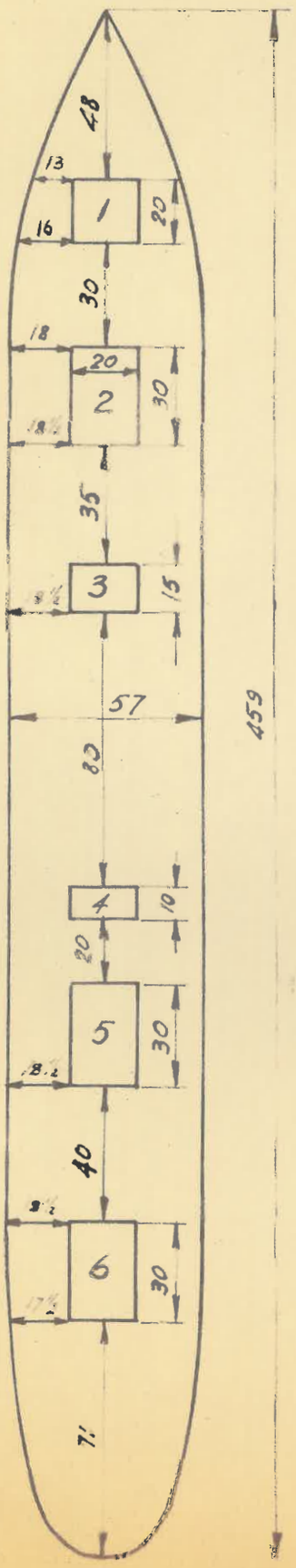


FIG. 1C

TWEEN DECK

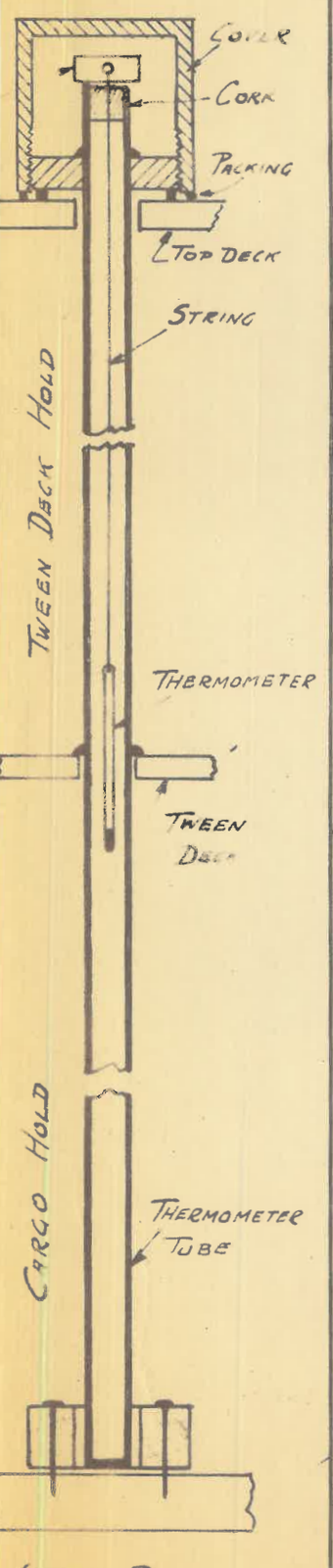
FIG. 1D

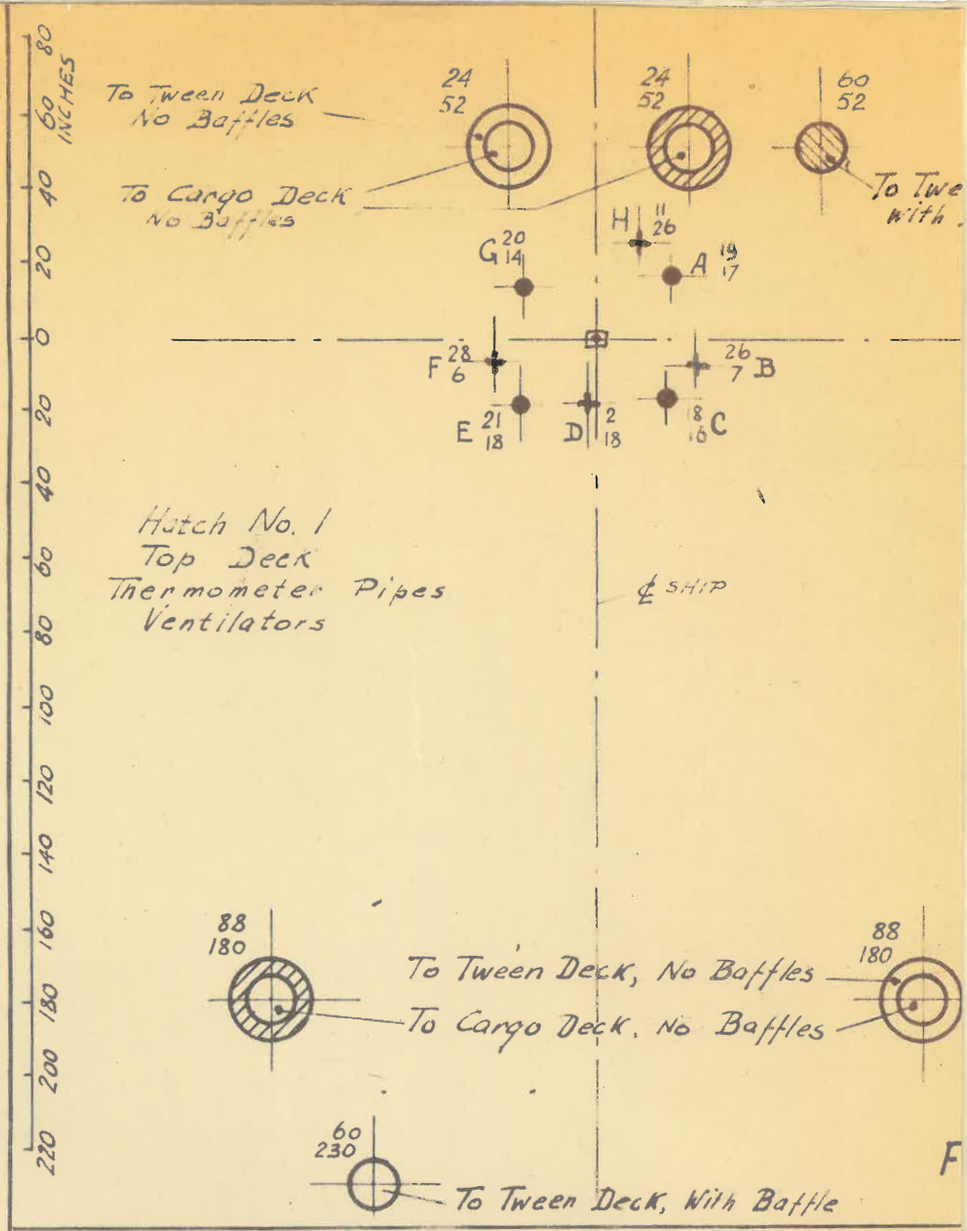
FLOORS CARGO DECK OR TANK COVER

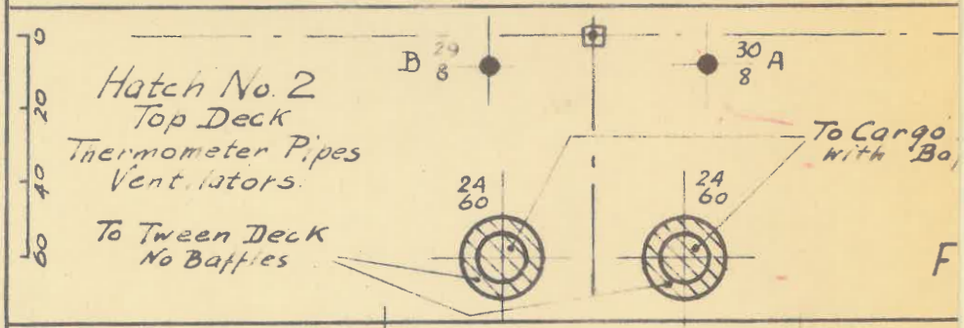
THERMOM. TAB

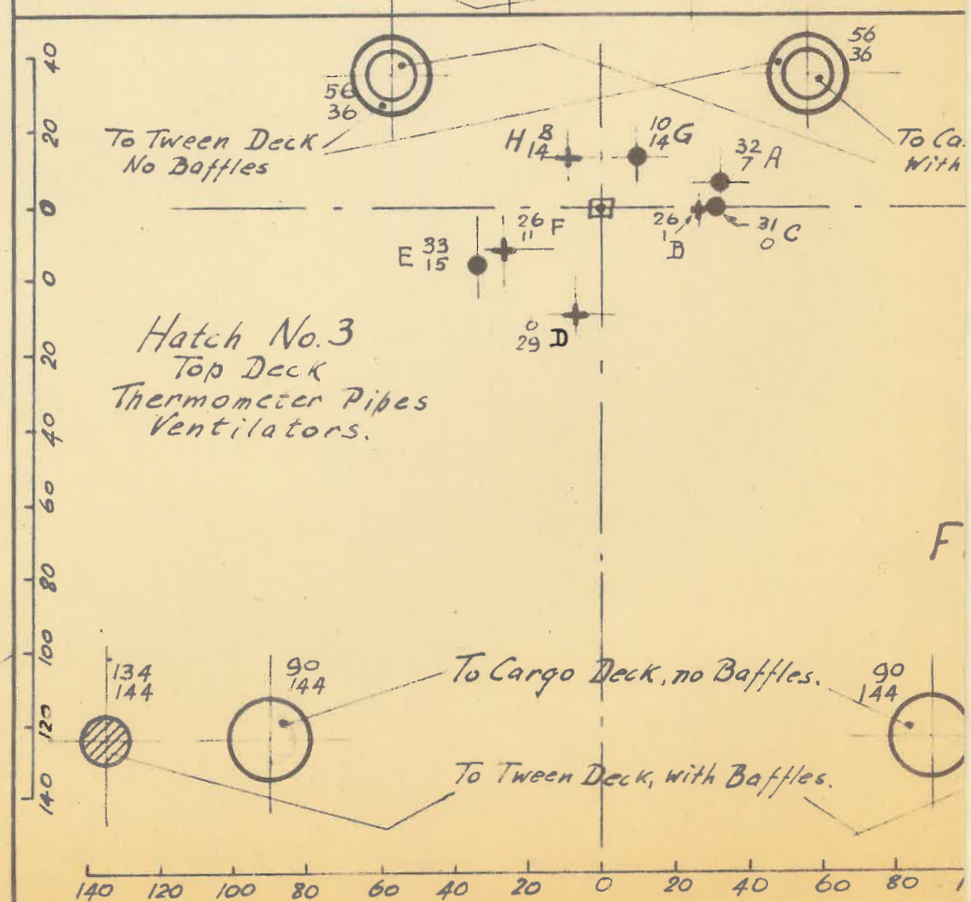
IG. 1E.

TUBES


COVER
CORK
PACKING
TOP DECK
STRING
TWEEN DECK HOLD
THERMOMETER
TWEEN DECK
CARGO HOLD
THERMOMETER TUBE
LOWER DECK OR TANK COVER


INCHES
To Tween Deck No Baffles
To Cargo Deck No Baffles
24 52
24 52
60 52
To Twe with
H 11 26
G 20 14
A 19 17
F 28 6
E 21 18
D 2 18
26 7 B
8 16 C
Hatch No. 1
Top Deck
Thermometer Pipes
Ventilators
℄ SHIP
88 180
To Tween Deck, No Baffles
To Cargo Deck. No Baffles
88 180
60 230
To Tween Deck, With Baffle
F


B 29 8
30 A 8
Hatch No. 2
Top Deck
Thermometer Pipes
Ventilators.
To Cargo with Ba
24 60
24 60
To Tween Deck No Baffles
F


56 36
56 36
To Tween Deck / No Baffles
H 8 14
10 14 G
32 7 A
To Ca With
E 33 15
26 11 F
26 1 B
31 0 C
0 29 D
Hatch No. 3
Top Deck
Thermometer Pipes
Ventilators.
F
134 144
90 144
To Cargo Deck, no Baffles.
90 144
To Tween Deck, with Baffles.

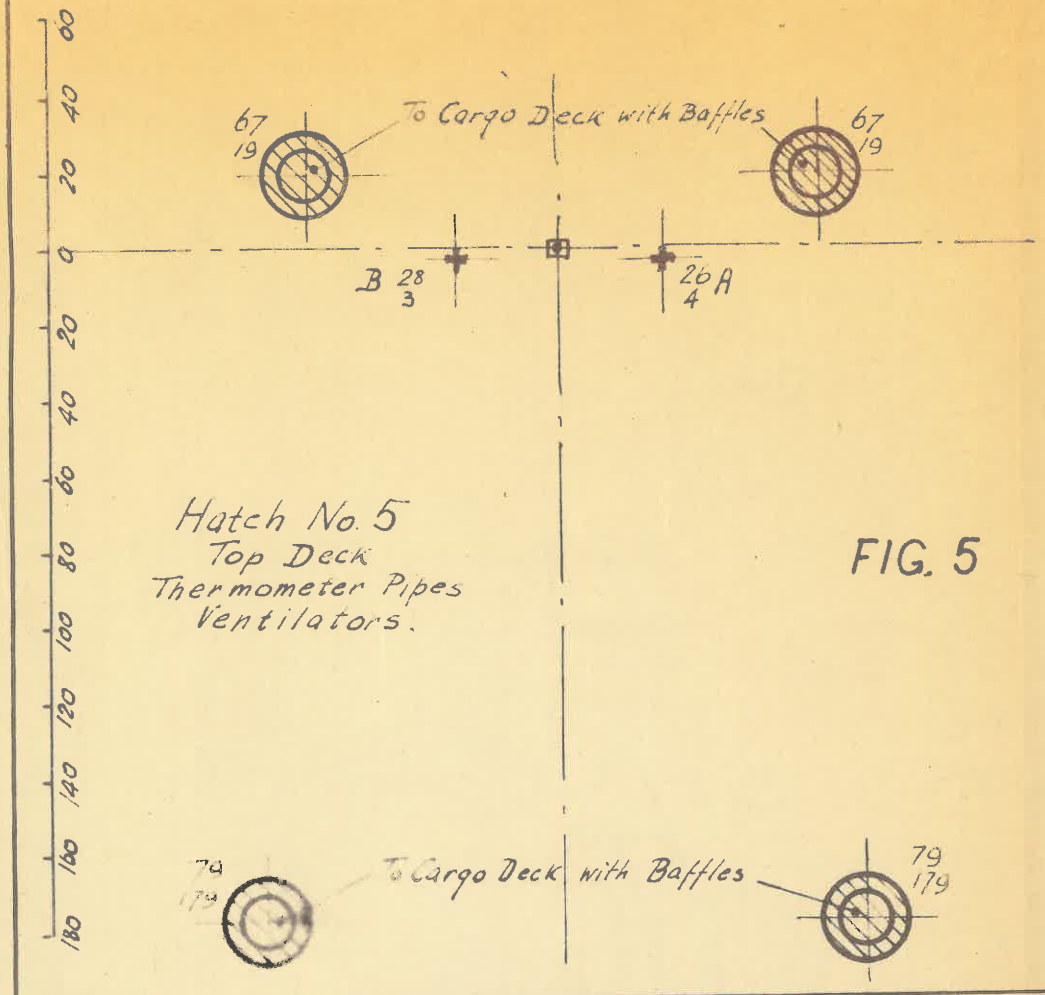


FIG. 5

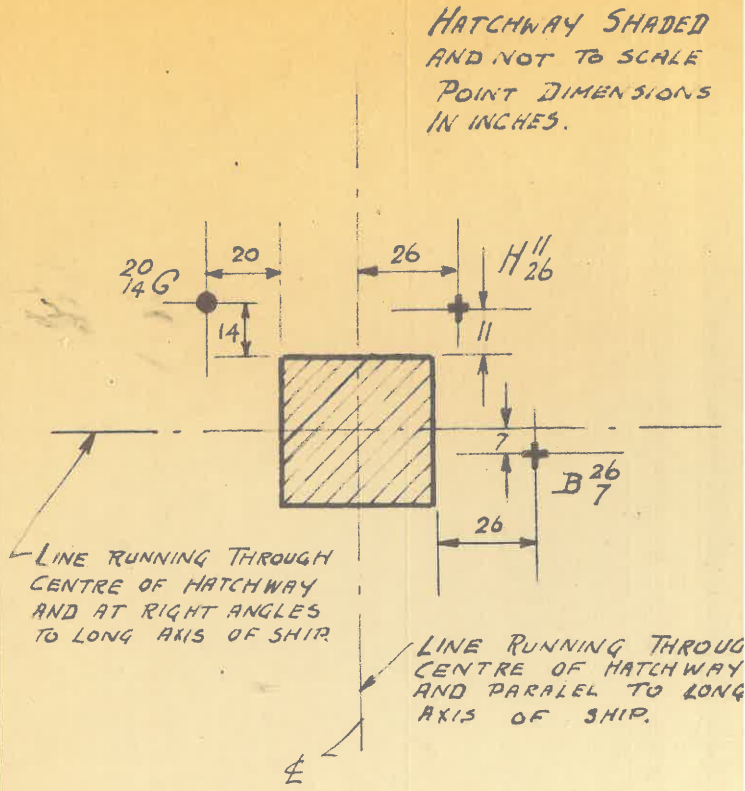


FIG. 7

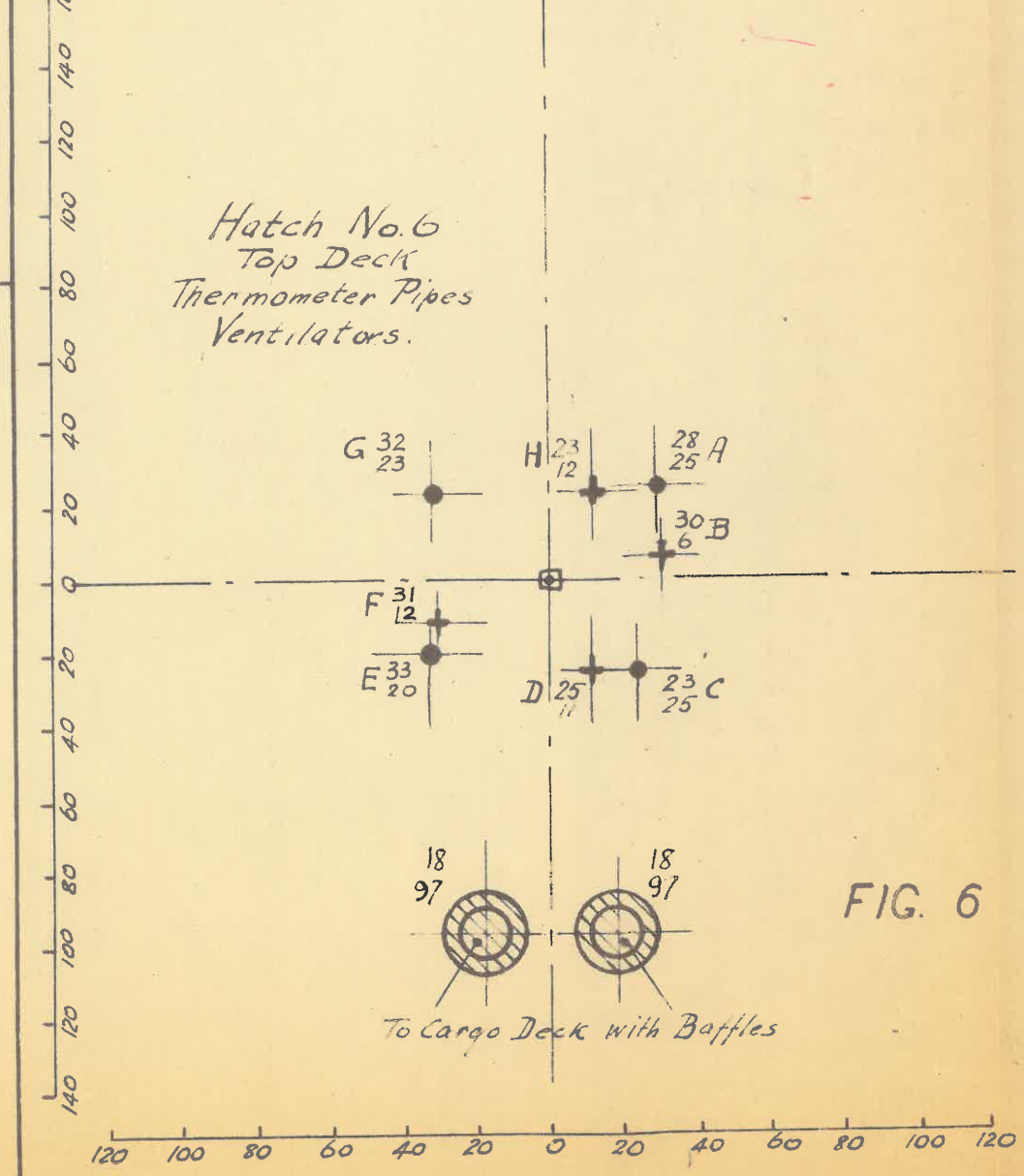


FIG. 6

NOTE: In Figs. 2, 3, 4, 5 & 6,

Shaded parts of Ventilators were sealed off during the tests.