DEPARTMENT OF TRANSPORTATION

COAST GUARD

MARINE CASUALTY REPORT

SS SILVER DOVE; CARGO SHIFT AND SINKING
IN THE NORTH PACIFIC OCEAN ON 2 APRIL 1973
WITHOUT LOSS OF LIFE

U.S. COAST GUARD
MARINE BOARD OF INVESTIGATION REPORT
AND COMMANDANT'S ACTION

ACTION BY
NATIONAL TRANSPORTATION SAFETY BOARD

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16.Abstract At 0937 on 31 March 1973, the freighter SS SILVER DOVE, en route from Guam to the Panama Canal with a bulk cargo of raw sugar, listed suddenly to port; the vessel sank 41 hours later 180 miles southwest of Johnston Island. Water had been leaking through a crack in the hull for several days; since the crew's attempts to repair the hull were unsuccessful, the vessel had stopped in Guam for temporary repairs. After leaving Guam, the leak continued, however, and the ship listed slightly to starboard. The sudden list to port occurred when the master shifted weight to the port side to correct the starboard list. The crew was rescued before the ship sank.

The National Transportation Safety Board determines that the probable cause of the sinking of the SILVER DOVE was the loss of transverse stability when the master was unable to assess the vessel's stability and incorrectly transferred fuel and water at a time when a crack was allowing seawater to leak into the sugar cargo. Contributing factors were the inability of the repair crew to repair the crack in the hull properly, the Coast Guard inspector's release of the ship without insuring proper temporary repairs because he had no inspection instructions, the inability of the ship's crew to remove the leaking water, and the creation of empty cargo space when the sugar dissolved to form the viscous sugar-water solution.

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SS SILVER DOVE
CARGO SHIFT AND SINKING
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ACTION BY THE NATIONAL TRANSPORTATION SAFETY BOARD

This casualty was investigated by a U. S. Coast Guard Marine Board of Investigation, which convened at Honolulu, Hawaii, on 7 April 1973. The National Transportation Safety Board has considered only those facts in the investigative record which are pertinent to the Safety Board's responsibility to determine the cause or probable cause of the casualty and to make recommendations.

SYNOPSIS

At 0937 on 31 March 1973, the freighter SS SILVER DOVE, en route from Guam to the Panama Canal with a bulk cargo of raw sugar, listed suddenly to port; the vessel sank 41 hours later 180 miles southwest of Johnston Island. Water had been leaking through a crack in the hull for several days; since the crew's attempts to repair the hull were unsuccessful, the vessel had stopped in Guam for temporary repairs. After leaving Guam, the leak continued, however, and the ship listed slightly to starboard. The sudden list to port occurred when the master shifted weight to the port side to correct the starboard list. The crew was rescued before the ship sank.

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FACTS

The SILVER DOVE had experienced leakage and damage to cargo in hold No. 3 before 7 March 1973 when it arrived in Batangas, Philippine Islands, to be loaded with a bulk cargo of raw sugar. Wasted sections through which water could enter had been discovered previously in cargo vent trunks on the main deck near the ship's superstructure. These vent trunks were cropped off flush with the deck and sealed shut with welded metal plates. To detect possible additional leakage from other sources, two 1 1/4- by 4-inch pipe nipples were installed in the bulkhead between No. 3 lower hold and the machinery spaces about 1 1/2 inches above the double-bottom tank tops.

At Batangas, the sugar owner's cargo surveyors inspected the vessel's holds to determine their suitability for carrying a bulk sugar cargo. In addition to other prerequisites for loading the sugar, they ordered construction of a wooden box around the fuel oil vent to the No. 3 starboard double-bottom tank in the after starboard corner of No. 3 lower hold where a spill had occurred on 9 March.

A total of 10,300 long tons (LT) of sugar was loaded between 10 March and 16 March. Hold No. 3, which was the largest hold of the SILVER DOVE and which had refrigerator boxes constructed around the perimeter of its lower 'tween spaces could hold about 2,902 LT of sugar cargo. The total volume of hold No. 3 was 147,330 cubic feet; the volume of the lower section of the hold was 89,400 cubic feet.

Based on the cubic capacity and the weight of cargo loaded, the average cargo stowage factor 1/ was 50.77 cubic feet per LT. Also, the lower hold would have contained 1,762 LT of bulk sugar if the cargo was evenly distributed among the lower hold, lower 'tween space, and upper 'tween space.

According to the ship's log, the average draft after loading was 29 feet, 8 inches. The vessel had a 3° starboard list which the crew considered normal. The chief mate's stabiloguage computation of the SILVER DOVE's metacentric height was 3.4 feet upon sailing. The computation was based on the loaded condition and considered the effect on the metacentric height of liquid free surfaces such as those that existed in the Nos. 2 port and starboard double-bottom tanks which were about half-full of fuel.

The SILVER DOVE departed Batangas at 0800, 16 March 1973, en route to the Panama Canal. About 1800, 17 March, the chief mate found that water on the deck of the starboard lobby was coming from one of the fan rooms in the lower 'tween space of No. 3 hold. Inside the fan room he discovered a horizontal crack in the hull measuring about 8 inches long, located about 6 feet below the waterline, and centered on frame 100. This area had been inspected earlier during searches for leaks and some sheathing had been removed.

The chief mate formed a patch of rubberized material backed by 2-inch by 6-foot planks, wedged in place, around which concrete was poured. This effectively reduced the waterflow and most of the accumulated water was removed by a bucket brigade. The drain line which usually removed water from this area had become clogged by debris from the removed sheathing insulation; there was also testimony that this line had been poorly maintained and had already been clogged by corrosion. A portable, air-driven, 15-gpm capacity pump was not effective in removing the water because it lacked an adequate air supply.

1/ The stowage factor is the number of cubic feet that is occupied by 1 long ton (2,240 pounds) of a commodity when it is stowed normally.

The next morning, 18 March, it was apparent that part of the patch was inadequate. The concrete aft of frame 100 was torn out and replaced with a canvas bag filled with "duck seal" (pliable putty), which was shored and wedged into place.

In spite of these patches, however, water continued to flow in through the crack during the next two days. A second cement patch was applied on 19 or 20 March and the vessel was stopped twice in unsuccessful attempts to place a canvas patch on the outside of the hull to be secured with lines passing under the hull.

On 19 March, a crewmember removed the cap on the starboard pipe nipple located in the bulkhead between the machinery spaces and No. 3 hold and a stream of granular sugar came out. It was followed a few minutes later by a stream of brown water, which sprayed out about 15 feet into the machinery spaces for several minutes. Smaller amounts of a sugar-water mix flowed out later; one flow lasted for several hours. No mixture flowed from the port pipe nipple, and samples made through that nipple were of normal consistency.

The SILVER DOVE was diverted to Guam for repairs, where it arrived on 21 March. The owner's surveyor, the production superintendent of the Dillingham Corporation ship repair facility, the vessel's agent, the Commanding Officer, Marine Inspection Division (OCMI), Guam, and a junior Coast Guard officer inspected the hull plate around the crack late that day. A list of 6° to port had been induced by the crew to raise the crack closer to the waterline and to reduce the water pressure on the crack. The temporary patch was not removed for the inspection because the OCMI was satisfied with the crack's description given to him and he did not want to cause any more flooding. Drilling of the crack ends was not attempted because it would have to be done below the waterline and it would have disturbed the area's hull plating, which was considered wasted. Instead, the officials agreed upon and ordered a temporary concrete patch inside a fabricated steel box to be installed the next day, 22 March.

While preparations were made to repatch the crack, several persons, including the owner's surveyor, the OCMI, and the shipyard supervisor, noticed general deterioration and pitting of the hull plating.

The concrete patch, made from Portland cement and coral sand, was not complete when the OCMI inspected it around 1845 on 22 March. He issued a requirement that permanent repairs be made before 1 June 1973. He also suggested that the SILVER DOVE's master delay sailing until after midnight to allow the concrete the 6 to 8 hours to harden as recommended by the repair crew. However, the steel box required more mixture than was originally estimated and the final batch of cement was not added until 2100.

The port list, created earlier to facilitate inspection and repair of the crack, was corrected and the SILVER DOVE sailed from Guam at 0048 on 23 March. A small amount of water flowed from the top of the patch early that day and the hull appeared to pant in the area of the patch. No water flowed out of the nipples into the machinery spaces when the nipple caps were removed.

By 27 March, the vessel had developed a starboard list of about 5° which the chief mate began to correct by fully ballasting the No. 4 port aft deep tank. The next day, the SILVER DOVE lost fires in both boilers because of water in the fuel in the No. 3 starboard double-bottom tank and in the starboard settler tank. Later, water was discovered leaking into a wasted area of the fuel oil vent line to the No. 3 starboard double-bottom tank; the wasted vent line was located behind the sheathing insulation near the crack.

On 29 March, the starboard fan room, lobby, and adjacent inboard refrigerator box was inspected; inspection revealed an increased accumulation of water. The No. 3 hold's starboard bilge well was being pumped, and the vessel still listed about 5° starboard.

On 30 March, fuel from the No. 3 starboard double-bottom tank was transferred to a port deep tank. Another hull leak, through a crack 14 to 16 inches long, was discovered between frame 101 and the after bulkhead in the starboard fan room. The new crack was patched with canvas bags filled with "duck seal." During the night, additional fuel was transferred from starboard to port tanks.

About 0700 on 31 March, a 2° starboard list was noted on the bridge. The engineroom clinometer showed the vessel on an even keel about 0830. A list to port began at 0925 and increased to 22° by 0937. The crew then began to abandon the SILVER DOVE, which sank 41 hours later on 2 April 1973.

ANALYSIS

Inadequate Temporary Repair

The effectiveness of a patch made with Portland cement depends primarily on adhesion of the mix to the steel hull around the crack. To achieve a strong bond, the surface must be properly prepared and the patch zone protected from stress fluctuations and vibrations while the cement is setting up; a bond's strength increases with time. Several types of Portland cement mixes can be used to make an effective patch within the time available to develop a strong bond.

The cement used to patch the SILVER DOVE both at sea and at dockside required more time to set than was provided. Special cement mixtures that set up quickly would have been necessary to patch the ship effectively at

sea since the stress fluctuations and the hull vibrations could not be reduced for long periods of time. The vessel was allowed to sail from Guam within 7 hours of the first cement pour and only 4 hours after the final pour, insufficient time for the patch to bond adequately.

Cement can bond well to a corroded steel surface from which loose rust and scale have been removed. However, unremoved scale will prevent a strong, watertight bond from forming. Conflicting evidence indicates that the ship's wasted steel surface may not have been cleaned.

It is evident that the ship's personnel, contracted repair personnel, and Coast Guard inspection personnel were not familiar with proper procedures for fabrication of cement patches. Coast Guard inspection instructions do not include specific criteria for inspection and approval of hull crack repairs made with Portland cement.

Development of Conditions for Potential Cargo Shift

It is also evident that those involved in determining the SILVER DOVE's seaworthiness were not aware of the significance of the changes that would be produced in the bulk sugar cargo when it mixed with seawater. The sugar-water mix is a molasseslike substance which has a smaller cargo stowage factor, i.e., a greater density, than either of its components. Therefore, a sugar cargo occupies less space when water is added. The stowage factor ranges from 40 to 50 cubic feet per LT for sugar and is 35 cubic feet per LT for seawater. A sugar-water mix that is 10 percent water by weight has a stowage factor of about 23.6 cubic feet per LT and a mix that is 20 percent water has a stowage factor of about 24.8 cubic feet per LT. 2/ (See figure 1.)

This reduced stowage factor affects a ship's stability for two reasons. First, since the space that the cargo occupies is reduced significantly as the sugar contracts, the sugar-water solution can flow toward the void created and exert a moment of transference 3/ when its free surface moves. A mixture that is 20 percent water will be reduced to about 70 percent of the sugar cargo's original volume; this would leave a 30 percent void into which cargo could shift.

Second, because of its greater density, the moment of transference that a given volume of transformed cargo creates as it shifts into a void is greater than the moment of transference that would have been created by a shift of dry cargo. With wet sugar, a mixture containing 20 percent water will be twice as dense as dry sugar.

2/ Polarimetry, Saccharimetry, and the Sugars, U.S. National Bureau of Standards Circular C-440; 1967.

3/ The moment of transference is the moment created by a shift in the center of gravity of a volume of fluid which is able to flow into an empty space under the influence of ship motions.

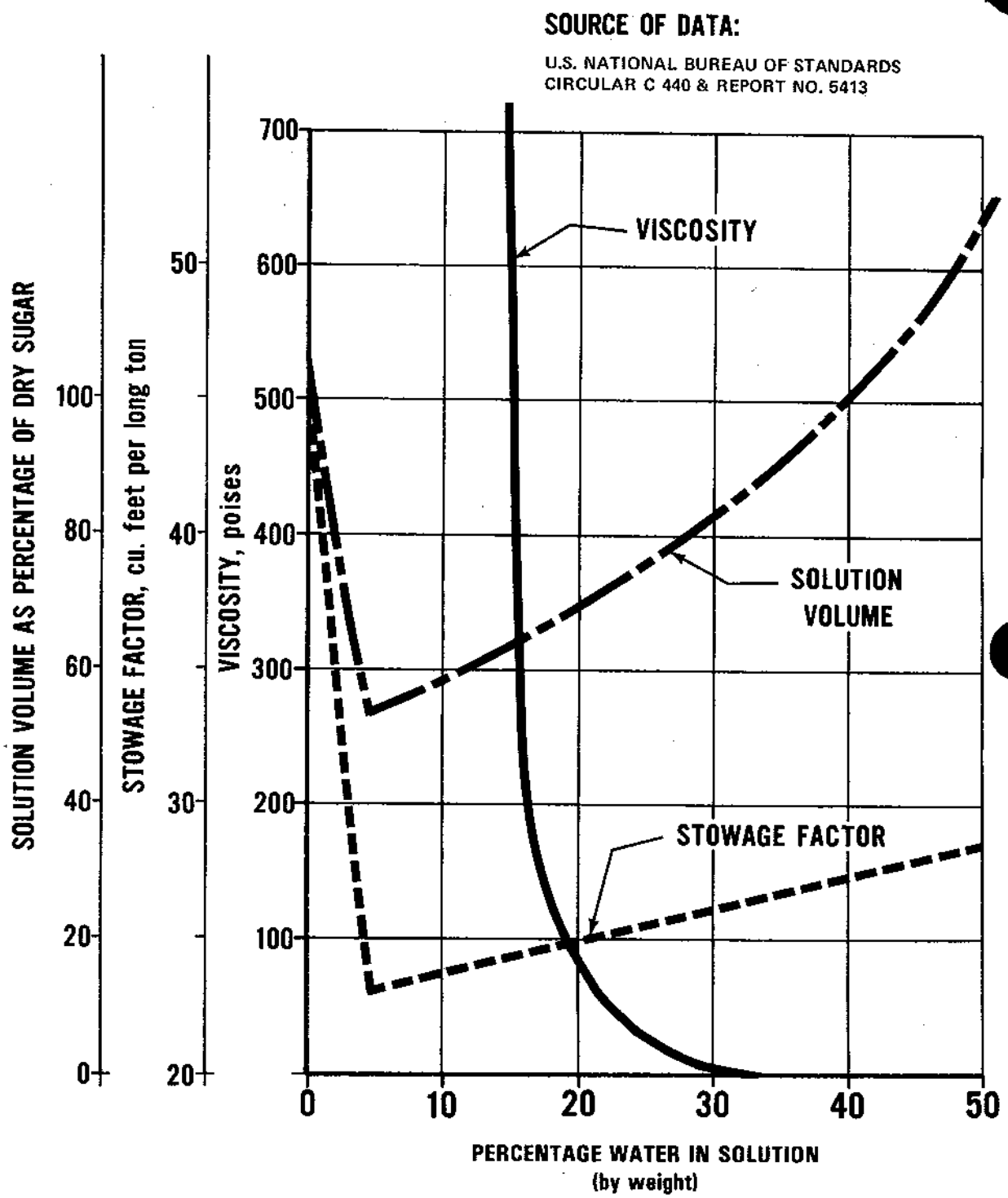


FIGURE 1. CHARACTERISTICS OF SUGAR SOLUTIONS

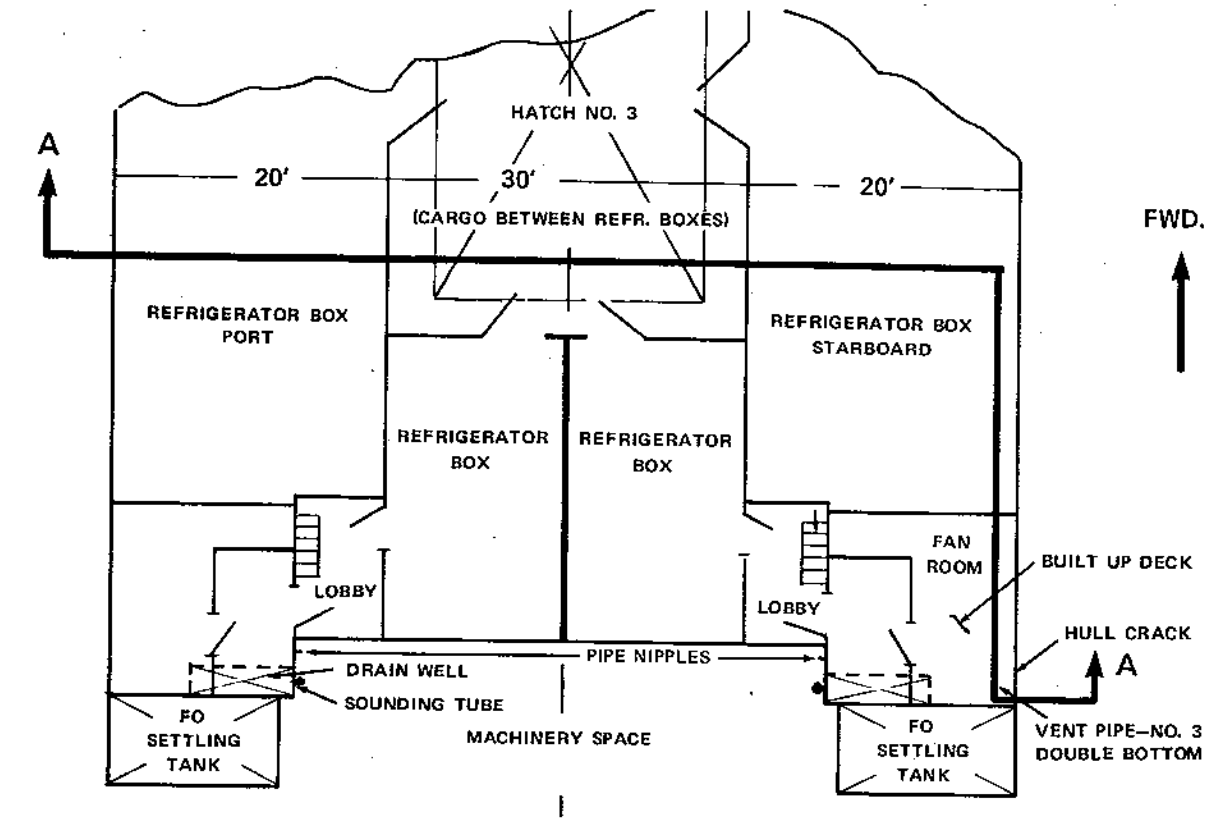
Raw sugar can also develop sufficient strength to support itself over regions where voids or cavities are created by the addition of water. Because of this, raw sugar in the SILVER DOVE's lower 'tween space and above may have remained above the hatch beams instead of feeding into the void that was created when sugar in the lower hold contracted as water was added. (See figure 2.)

Another change in sugar's physical properties, which is significant to the manner in which the list to port developed in this case, is the reduction in a sugar solution's viscosity as water is added. (See figure 1.) The viscosity reduces sharply until the solution is 20 percent water and then it continues to reduce more gradually as more water is added. A solution of 10 percent water would flow slowly in response to changes in the ship's angle of heel, whereas a solution of 20 percent water would flow faster.

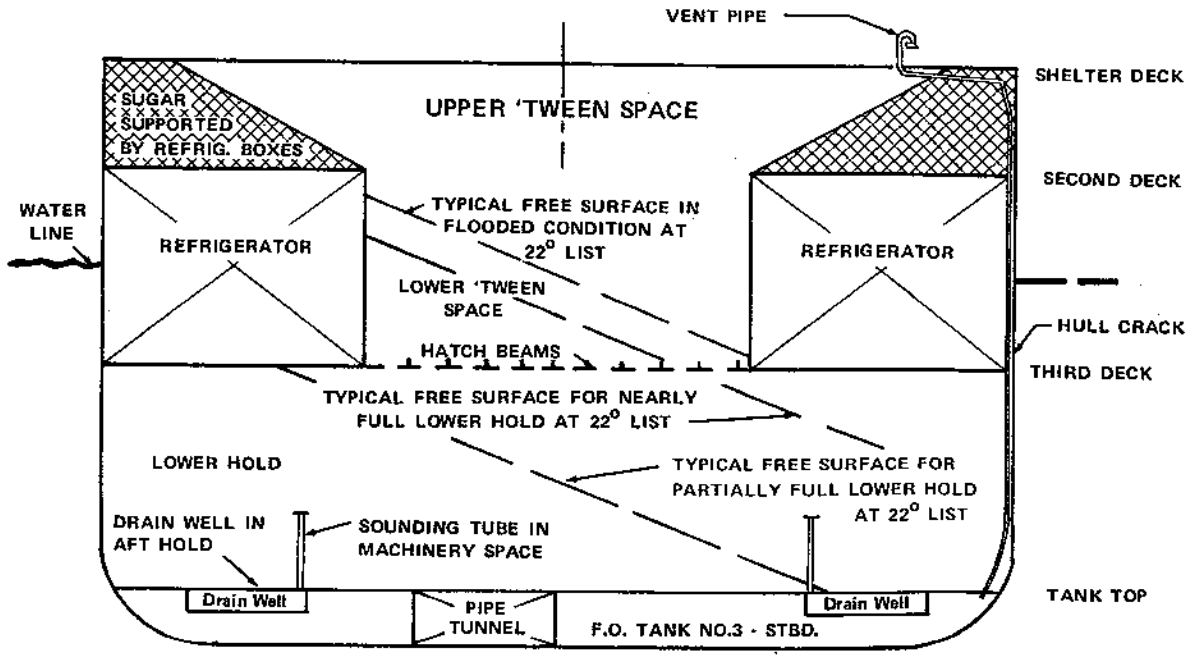
If water infiltrates sugar faster than the sugar can dissolve into a homogeneous solution, gravity causes the excess water to flow through the sugar. This flow washes the liquid coating off the wet sugar crystals creating a solution of increasing viscosity. As the solution's gravity flow slows, it causes the infiltrating water to rise to the surface near its source. Normal vessel motions would be expected to accelerate water infiltration into raw sugar. If the infiltration is stopped or reduced, the liquid concentration near the source will diffuse into the surrounding sugar.

The results of this infiltration process were observed on the SILVER DOVE. When the cap was removed from the starboard pipe nipple before the ship arrived in Guam, a stream of granular sugar, followed by brown water, flowed out. This nipple was located in a bulkhead in the lower hold near the wet sugar. After the ship departed Guam, no water flowed out because water was not entering as quickly since the crack had been temporarily sealed and because the list to port induced in Guam to facilitate repairs had allowed the water already in the hold to diffuse into the sugar. However, since the water was entering on the starboard side, the amount of water in the sugar farther from the starboard side decreased, as confirmed by samples taken from a port pipe nipple.

The existence of a homogeneous solution of water and sugar was not a likely, or necessary, condition for a cargo shift. It was only necessary for the sugar-water solution on the starboard side to flow into a void on the port side. A large void could have developed on the port side if the dry sugar contracted into a concentrated solution containing just 10 percent water. A solution containing 20 percent water on the starboard side would have become sufficiently liquid to flow into the port void as the ship listed. (A heterogeneous solution which contained about 10 percent water on the port side and 20 percent water on the starboard side would have been a likely distribution of water considering the water was infiltrating from the starboard side;



PARTIAL PLAN VIEW OF THIRD DECK



SECTION VIEW – A-A LOOKING FORWARD

FIGURE 2. CARGO HOLD NO. 3

this distribution would have required the infiltration of less than 315 LT of water. More than 315 LT of water could have leaked through the crack before the SILVER DOVE listed 22°.)

The Coast Guard estimated that the heeling moment which the master of the SILVER DOVE applied to correct the list to starboard was 12,750 foot-tons. The Safety Board believes that this estimate is too high because it is based on 380 LT of ballast in the No. 4A port deep tank; the Stability Booklet [4/] for the SILVER DOVE indicates that tank's maximum capacity is 350 LT. The net offcenter weight caused by leakage into the three remaining No. 4 deep tanks was only about 4 LT to port. Using an estimated 354 LT net differential for all No. 4 deep tanks instead of the 380 LT differential, the Safety Board estimates that the heeling moment was 12,360 foot-tons. This moment should have caused about a 10° list to port had no other weight been shifted.

To determine the conditions in hold No. 3 of the SILVER DOVE that caused the 22° list to port, the moment of transference at 22° list was computed for several possible water-sugar solution ratios, i.e., stowage factors, as a function of empty space available for cargo shift. Since water infiltration into sugar results in a solution of lower volume and higher density than dry sugar cargo, the center of gravity in the hold is lowered. In turn, this process causes the vessel's KG, which is the distance between the vessel's center of gravity and its keel, to be reduced and thereby increases its righting moment. The righting moment at 22° list that corresponded to each of these cargo conditions also was computed. For each selected stowage factor, the ratio of moment of transference (MT) to the residual righting moment (RRM) was plotted graphically as a function of the percentage of the lower hold volume occupied by solution. (See figure 3.) The residual righting moment is the actual righting moment at 22° list minus the 11,460 (12,360 x cos 22°) foot-ton heeling moment that was applied by the crew. This ratio, MT:RRM, will equal 1 when the list is 22°, will be less than 1 for angles less than 22°, and will be more than 1 for angles greater than 22°.

For each sugar-water solution ratio, there is a maximum volume of solution that can be formed in the hold; it is determined from the dry sugar volume and the ratio of water and raw sugar in solution. (See figure 1.) The maximum volume of a solution containing 15 percent water and only the sugar in the lower hold would occupy about 65 percent of the lower hold space. A solution of 40 percent water and only the sugar from the lower hold would require slightly more space than that available in the lower hold. If the sugar above the hatch beams as well as that in the lower hold mixed with water to form a solution that was 15 percent water and 85 percent sugar, it would occupy about 81 percent of the lower hold space. (See figure 3.)

4/ Stability Booklet for C3-S-A5 Type Hull, prepared by J. J. Henry Co., Inc., New York, and approved by U.S. Coast Guard, January 5, 1968.

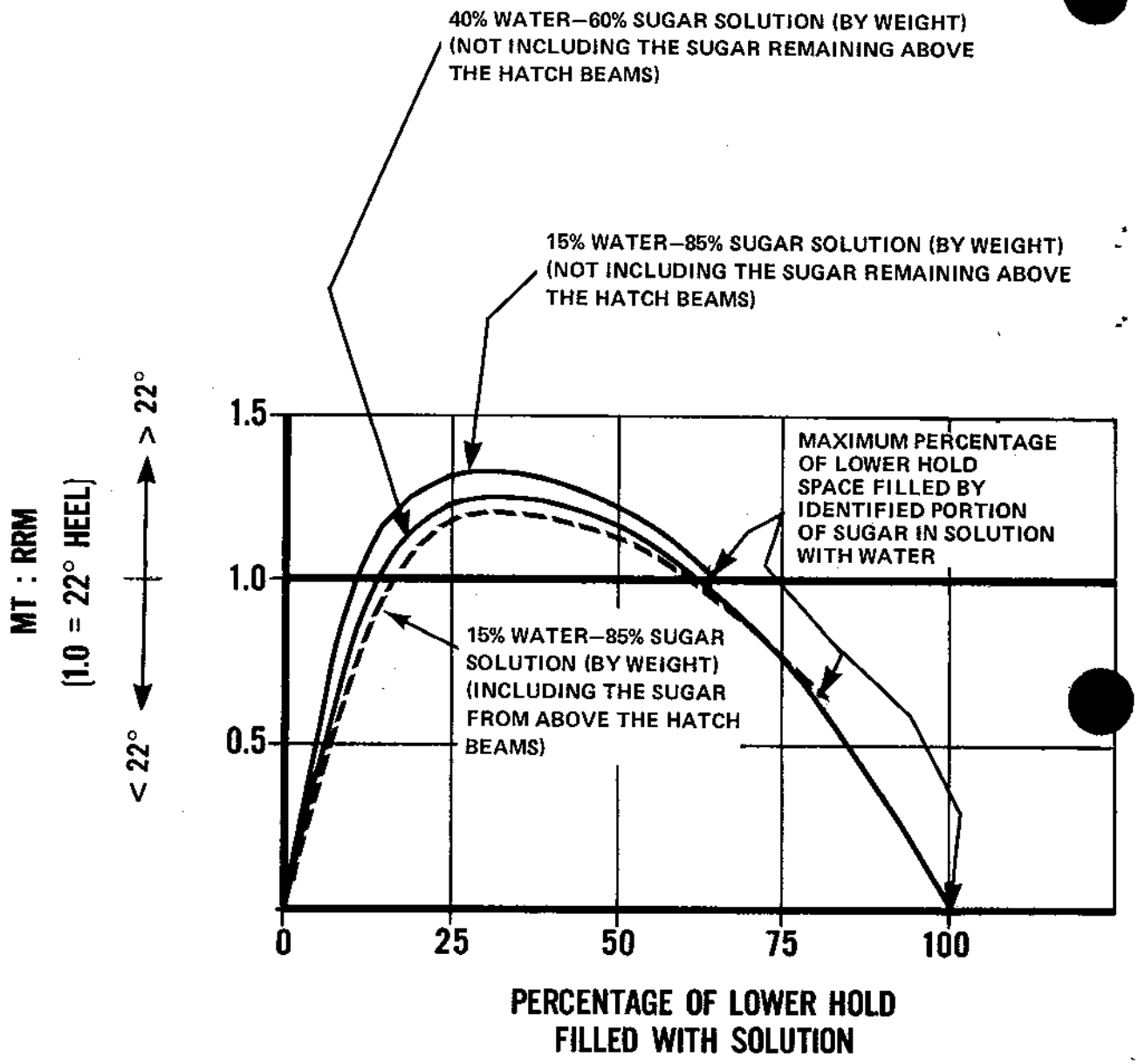


FIGURE 3. RANGE OF CARGO CONDITIONS NECESSARY TO CAUSE 22° LIST

For the ratios of water and sugar considered, the 22° list of the SILVER DOVE would have developed when the sugar-water solution filled about 65 percent of the lower hold space. Greater quantities of solution would not have provided a sufficient void for a cargo shift to cause a 22° angle of heel. If the solution filled between 10 and 65 percent of the lower hold space, the angle of heel would have exceeded 22°. Quantities of solution in less than 10 percent of the lower hold space would not have weighed enough to cause the SILVER DOVE to heel 22°.

Pumping the solution overboard would only have increased the SILVER DOVE's angle of heel until the solution remaining occupied less than 10 percent of the lower hold volume. Not only would it have been necessary to pump at least 1,800 LT of solution overboard to make this reduction, but the ship's heel angle would have had to increase to some maximum angle and then decrease again. Since a steadily increasing list to port was observed, the quantity of water and sugar which caused the 22° angle of heel had to have occupied nearly 65 percent of the lower hold volume. Without pumping a considerable amount of sugar and water solution overboard, the 22° angle of heel would have been caused by mixing of the sugar in the lower hold in a solution with between 15 and 20 percent water.

Nearly 500 LT of solution had to shift to cause the 22° angle of heel. The Coast Guard's calculation of the necessary weight shift, using a KG of 27.2 feet, differed from that of the Safety Board which determined the KG to be 25.9 feet before correcting for the effects of water in the cargo. The Coast Guard probably did not adjust its calculation to correct for the loss of free surface in the initially half-empty No. 2 double-bottom tanks and probably applied too large a correction for the free surface in No. 5 deep tanks at 22° heel angle.

The Safety Board also considered the possibility that weight might have shifted in hold No. 4, since water was leaking into the deep tanks below it. However, the hold was not large enough for a weight shift to develop a significant heeling moment.

Reduced Stability Not Detected

The starboard list and leakage should have warned the crew that the cargo was transforming and becoming hazardous to the vessel's stability. The large transverse dimension of No. 3 hold would have normally permitted a cargo shift to cause a noticeable change in the SILVER DOVE's handling and roll. However, until a significant quantity of water had mixed with the sugar, the solution would have been too viscous to flow from side to side in response to the vessel's rolling motion. Thus, a change in the vessel's motion characteristics could only have been detected after a serious condition developed. 5/

5/ The Liberian bulk carrier, M/V DROSIA, laden with sugar, sank suddenly with loss of life off Cape Hatteras on December 11, 1975. Although water was seen mixing with the sugar cargo, the crew did not become alarmed because the vessel continued to ride well.

Drains could detect water infiltration only if located near a source of entry or after the entire lower region of sugar had become fluid. It was only by chance that a starboard nipple was installed near enough to the leak to allow the engineroom watch to see that water had infiltrated the cargo. Again, because of a lack of knowledge the master did not realize the severity of the hazard.

A change in the ship's draft, which would indicate added weight, was not noticed on the SILVER DOVE because it was insignificant. Probably less than 200 LT of water had entered the ship en route to Guam and some of the solution it formed was pumped from the bilge. Thus, although the leakage was creating a hazard, the ship's draft would have only changed about 3 inches.

Possible Actions to Correct List

The master attempted to counteract the starboard list by transferring weight to port side but, because of the sugar-water solution, his actions worsened rather than improved the ship's transverse stability. However, there were several courses of action that he could have taken to correct the list.

First, he could have done nothing. If water had continued to leak into the hold, the free surface of the sugar solution would have risen to just below the waterline to equalize the pressure of the seawater outside and the pressure of the higher-density solution inside. If the hold had flooded to the equalization level, about 1,400 LT of water would have entered and increased the draft nearly 2 feet. The additional weight would have increased the vessel's righting moment and decreased the cargo's free surface moment of transference to less than 6 percent of the maximum possible moment of transference. This great reduction was possible because of the smaller transverse dimension in the lower 'tween space which would have limited the quantity and transverse distance of a cargo shift. If the hold had flooded to the waterline, the vessel's transverse stability would have increased significantly, although the flooding would have increased the longitudinal bending moment and would have increased the stresses on the bulkhead and on the hold bottom. However, if the vessel's strength was adequate, flooding might have been the safest occurrence.

Second, the master could have reduced the solution to a safe level, using the bilge pumping system. However, it would have been necessary to keep the solution volume, which could contribute to a cargo shift, from exceeding about 5 percent of the lower hold volume in order for pumping to be beneficial. Once a large volume of solution developed, pumping solution from the hold could have been detrimental to the vessel's stability.

Third, the master could have eliminated all significant unbalanced weights. Before the cargo's viscosity was reduced and the sugar solution

began to flow, the vessel listed to starboard because water weight was being retained in the sugar. If the master had realized that the viscosity of the sugar was decreasing and that any unbalanced weight shifted to compensate for the list to starboard could threaten the vessel's stability, he might have eliminated any differential transverse weight in fuel oil tanks and ballast tanks. If the only unbalanced weights on the vessel were those created by the cargo shift, the SILVER DOVE would not have listed more than about 15°. Under such conditions the vessel probably could have reached a port for repairs.

Fourth, the master could have ballasted the ship to correct the list. Ballast could have been added to the empty double-bottom fuel oil tanks and the deep tanks to improve the vessel's stability. Such action would have required a planned sequence of ballasting, an immediate elimination of unnecessary free surface of fuel oil or other liquids until the vessel had regained sufficient stability, and an evaluation of the vessel's strength. Both settlers could have been topped off to maintain power and propulsion, and seawater could have been added, if necessary, to bring slack oil tanks to about 98 percent full. The master would have had to evaluate carefully any free surfaces that were created during ballasting; however, because of their low depth-to-beam ratio, the moment of transference in the double-bottom tanks would be small at larger angles of heel.

Most of these alternatives for correcting the vessel's list required a technical evaluation which exceeded the capabilities of the persons involved. Such an evaluation requires expertise in ship stability and strength and a knowledge of the properties of bulk cargoes. In this case, a means of detecting the moisture content of the sugar was necessary in determining what action to take. Such technical assistance was not available to the master. Since he did not realize the hazards of water infiltration in certain water-soluble cargoes, he did not seek assistance from an expert on the matter. The Coast Guard's Officer in Charge of Marine Inspection (OCMI) also needs assistance in such highly technical matters. The Coast Guard should provide a quick, readily accessible technical service to its OCMI's who might otherwise be reluctant to seek assistance through the existing organization process. Such a service could also serve the needs of merchant mariners. Without a reliable assessment of a ship's condition, responsible persons may not be inclined to order costly repairs.

Need for Special and Improved Vessel Inspections

Methods to detect cracks in ships need to be improved significantly, particularly for older ships, which are likely to have more cracks, and for large, new ships, which have extensive areas to be inspected that often must be viewed remotely. The methods should detect cracks that may cause flooding and cracks that may cause serious structural failures. Instruments to aid in detecting cracks in plate steel have been developed and are used on steel bridges which, because of size or inaccessability, are difficult to inspect. Such aids could improve the effectiveness of the current visual inspection methods of ship hulls.

The SILVER DOVE's hull was inspected and certified seaworthy by the Coast Guard in June 1971 and was reinspected in drydock in May 1972. The American Bureau of Shipping (ABS) also performed a special periodic hull and machinery survey and an annual loadline inspection of the ship in May 1972. The hull crack in No. 3 hold may have existed during the inspections 10 months before it was finally discovered. The heavy rust, the scaling, the pitting, and the deterioration, which the owner's surveyor and the Coast Guard inspector in Guam found on the inboard side of the hull near the crack, and previous incidences of leakage into the cargo hold, indicate that a weak hull zone or the crack may have existed for a long time. The methods used for periodic inspections probably would not have detected a small, 8-inch hull crack that was above the waterline and covered on the inside by sheathing or other obstructions. When the Coast Guard inspector was looking for hull-side cracks from the drydock floor, he was at least 30 feet from the crack. Even after some of the hull sheathing in the ship's diffuser room was removed while the ship was in Saigon before sailing for the Philippine Islands, the crack was not found.

In addition to corroded hull plating behind the hull sheathing in No. 3 hold, Coast Guard and ABS inspections also failed to detect the extensive wastage of the vent systems on the SILVER DOVE. The discovery of ship defects depends on many factors and some defects may be missed; however, the extent of the wastage on the SILVER DOVE indicates that older vessels should be inspected more thoroughly.

Instead of increasing the inspection effort for selected hull areas as recommended by the Marine Board of Investigation, the Coast Guard plans to rely on a computer-based Vessel Inspection Information System to predict inspection needs based on previous hull and equipment inspections. Such an information system can be no better than the information put into it, and present inspections are not detecting some defects that threaten the safety of a ship. In fact, the present level of inspection could become more established or even reduced if the Coast Guard began to depend more on the system's inadequate stored information. If the Coast Guard increased inspection efforts for selected equipment and hull areas, the information system could receive higher quality data to enhance the usefulness, credibility, and chance of success of the planned information system.

A ship's hull plating thickness is checked during periodic inspections to determine if any large areas have lost more than the 25-percent thickness normally allowed by Coast Guard and ABS rules. Several points are checked and the readings averaged to obtain a thickness value. When the SILVER DOVE was inspected last, a point on each 6- by 26-foot gauged plate was checked. However, if a point was unusually thin, another point on the plate was checked and the average of the two readings was used as the true plate thickness. If the first reading had, by chance, detected a locally wasted area, that information was lost when the reading was averaged with another.

If an inspection is to warn of potential hull leaks, the accuracy of the low reading should be confirmed and the reading highlighted for further action rather than absorbed into an average figure.

Ultrasonic plate thickness readings are unreliable if the opposite side of the plate is covered with thick scale and rust as it was near the crack on the SILVER DOVE. Any readings taken on plating that is covered on the opposite side and that may not be free of heavy scale and rust should not be used. In fact, plating that has inaccessible areas on a side which cannot be maintained should be particularly suspect and should be gauged with more reliable methods such as drill testing.

General cargo vessels such as the SILVER DOVE are outfitted to carry a variety of cargoes, which generally can be classified as bulk or break-bulk cargoes. 6/ The outfitting for break-bulk cargoes may include refrigerated spaces with the necessary equipment, insulation, and ventilation systems. Such additional outfitting makes inspection of a cargo hold more difficult than the hold of a vessel that carries only bulk cargo and has minimal internal structure and fittings to obscure the inspection of hull plates and piping systems.

The hazard caused by leakage of seawater into break-bulk cargoes from hull cracks or wasted piping systems usually will be less severe than the hazard caused by leakage into bulk cargoes since break-bulk cargoes will not impair the efficiency of the bilge pumping system as much. Older general cargo vessels, less able to compete for the more profitable break-bulk trade and whose age and inherent difficulty of inspection increase the likelihood of seawater leakage, tend to carry bulk cargoes, some of which, when mixed with water, can threaten the vessel's stability. To reduce the risk associated with carrying bulk cargoes on older general cargo vessels, all such ships should receive a one-time special inspection for excessive wastage of hull plating that is covered by insulation and sheathing, and of piping systems that have openings outside the hull.

CONCLUSIONS

1. Cracks that were discovered in a starboard hull plate in the diffuser room in cargo hold No. 3 were large enough to permit a sufficient leakage of seawater to transform the bulk sugar cargo into a viscous liquid. Water accumulation near the crack hampered repair efforts and permitted an overflow to increase leakage into the lower hold; this water was not removed because of clogged drains in the area and the lack of an effective portable pump.

2. Cement patches applied to the cracks were ineffective in stopping the leakage because the ship's crew and contracted repairmen did not know the proper procedures for fabricating a cement patch.

6/ Bulk cargo is usually a homogeneous cargo stowed in bulk, i.e., loose in the hold and not enclosed in any container such as boxes, bales, bags, casks, etc. Break-bulk cargoes are enclosed within containers so that container-sized quantities are handled at one time.

3. The Coast Guard inspector released the ship without insuring proper temporary repairs because the Coast Guard does not have instructions for the inspection of temporary cement patches.

4. The mixing of seawater with bulk sugar forms a viscous liquid solution which can endanger a ship's stability. Because the solution volume is considerably less than that of dry sugar, a void is created into which the solution can flow. A void of about 35 percent of the dry sugar volume will be created by the presence of a solution containing 15 percent water.

5. The small quantity of seawater necessary to transform the bulk sugar into a liquid made detection of the impending hazard unlikely.

6. The master incorrectly added and transferred liquid weights to port to correct a starboard list because he was unable to assess the vessel's stability. His action caused a port heeling moment of 12,360 foot-tons while the SILVER DOVE was in a condition of reduced stability.

7. The 22° port list resulted from the combined effects of the master action and the mixing of water with sugar in lower hold No. 3. Less than 315 LT of seawater was sufficient to transform the cargo in lower hold No. 3 into a liquid and create a void into which slightly over 500 LT of the liquid could shift. This flow created a moment of transference of slightly over 24,000 foot-tons which, together with the crew-induced heeling moment, caused a 22° list. The 24,000-foot-ton moment alone would have caused the SILVER DOVE to heel about 15 degrees.

8. Alternative actions to correct the starboard list required an evaluation of a complex stability problem; the master did not have the capability of making such an evaluation.

9. Present Coast Guard inspection practices and techniques are not adequate to assure that all serious hull cracks and wastage, which can cause leakage and impair a vessel's strength, are detected during periodic inspections of older break-bulk cargo ships.

PROBABLE CAUSE

The National Transportation Safety Board determines that the probable cause of the sinking of the SILVER DOVE was the loss of transverse stability when the master was unable to assess the vessel's stability and incorrectly transferred fuel and water at a time when a crack was allowing seawater to leak into the sugar cargo. Contributing factors were the inability of the repair crew to repair the crack in the hull properly, the Coast Guard inspector's release of the ship without insuring proper temporary repairs because he had no inspection instructions, the inability of the ship's crew to remove the leaking water, and the creation of empty cargo space when the sugar dissolved to form the viscous sugar-water solution.

RECOMMENDATIONS

As a result of its analysis of this accident, the National Transportation Safety Board submitted the following recommendations to the Commandant, U.S. Coast Guard:

"Develop or adapt existing crack detectors to provide its marine inspectors with a reliable means of detecting small cracks in ship hulls and utilize such detectors once developed. (M-76-11) (Class III, Longer-Term Followup)

"Develop detailed procedures to be followed in making hull thickness measurements during periodic Coast Guard inspections. These procedures should insure that reliable ultrasonic readings are obtained, that low readings are highlighted as potential origins of cracks or leaks, and that areas covered by sheathing or insulation are measured by more reliable means such as drill gauging. (M-76-12) (Class II, Priority Followup)

"Conduct a one-time special inspection of all certificated U.S. seagoing break-bulk vessels constructed before 1965 to detect wastage of hull plating that is covered by insulation and sheathing and wastage of ventilation systems and piping systems that have openings outside the hull. This special inspection should be completed within 2 years. (M-76-13) (Class II, Priority Followup)

"Develop, with the assistance of the Portland Cement Association, guidelines for the use of cement for making watertight temporary repairs aboard ship and inspection of such repairs and issue these guidelines in a Navigation and Vessel Inspection Circular. (M-76-14) (Class II, Priority Followup)

"Develop standards for and require portable pump(s) with the necessary ancillary equipment to remove seawater which may leak into the cargo holds of ships which carry bulk cargoes. (M-76-15) (Class III, Longer-Term Followup)

"Identify those "dry" bulk cargoes which can threaten a ship's stability when water is added and publish this information with a description of the hazard in a Navigation and Vessel Inspection Circular. (M-76-16) (Class II, Priority Followup)

"Establish, with the assistance of the National Cargo Bureau, Inc., procedures for detecting water infiltration into bulk cargoes while the vessel is at sea. (M-76-17) (Class III, Longer-Term Followup)

"Establish a means to provide rapid technical advice to vessel masters and to Coast Guard field personnel regarding vessel stability and the effects of water entry into bulk cargo. (M-76-18) (Class II, Priority Followup)

"Advise masters of vessels that carry bulk cargoes that may affect ship stability adversely when water is added to alert the Coast Guard immediately if water leaks into the cargo. (M-76-19) (Class II, Priority Followup)"

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ WEBSTER B. TODD, JR.
Chairman

/s/ KAY BAILEY
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PHILIP A. HOGUE
Member

/s/ WILLIAM R. HALEY
Member

September 10, 1976

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

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U.S. COAST GUARD (G-MVI-3/83)
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5 JAN 1976
5943/SILVER DOVE
C-14 Bd

Commandant's Action

on

The Marine Board of Investigation convened to investigate the sinking of the SS SILVER DOVE in the North Pacific Ocean on 2 April 1973 without loss of life

1. The record of the Marine Board of Investigation convened to investigate subject casualty has been reviewed; and the record, including the Findings of Fact, Conclusions and Recommendations, is approved subject to the following comments.

REMARKS

1. The Commandant concurs with the Board's conclusions that the SS SILVER DOVE capsized and sank after developing hull fractures in way of, or near, plate SG-12. The ingress of water through these fractures caused the vessel to take on a starboard list. This was due to the combined effect of the added weight of the water and the shifting of the sugar cargo, which had become fluid due to the flooding water. To alleviate the increasing starboard heeling moment, the vessel was counterballasted to port. A sudden shift of the sugar cargo and flooding water to port combined with the ballasting caused a 22^{o} list to port. Additional water probably entered through hull fittings in or above the upper 'tween deck (freeboard deck), and progressed longitudinally through the tonnage openings in the transverse bulkheads flooding the remaining cargo holds and machinery spaces until the vessel sank.

2. It was the Board's observation that the investigation unearthed certain inadequacies of Coast Guard biennial inspection and drydock procedures as well as the American Bureau of Shipping condition and special survey procedures. The diligence of the involved inspection personnel who supervised the temporary repairs in Guam was also criticized.

Although a casualty of this nature implies deficiencies existed somewhere and at some personnel level, there is no way to fully reconstruct the casualty without the presence of the hulk. The fact remains that we are operating from conjecture and on a basis of "best estimate" as to cause and personnel deficiency. The Commandant's response to the many unanswered questions that such tragedies introduce is best described in the action portion of recommendations1 and 2. There are certainly lessons to be learned--and this is where emphasis will be placed.

With respect to the criticism of the inspection personnel in Guam, including the OCMI, it can only be said, however tritely, that hindsight is clearer than foresight. The group of experienced repair personnel which included American Bureau of Shipping, U. S. Coast Guard, private surveyor, Dillingham Ship Repair Superintendent, and the ship's officers all felt the wasted area was exposed and this was the problem area to be dealt with. When divers plugged the crack from the outside all ingress of water had ceased, indicating to all there were no further hull failures. The perimeter of the wasted area was exposed and the steel hull plating adjacent to it was in satisfactory condition. Therefore, there was no more reason to remove more insulation in that area than there was to question the soundness of the hull in any other part of the vessel. The fact that the vessel had undergone Coast Guard drydock inspection and American Bureau of Shipping special survey #5 less than one year previous was sufficient cause not to require the vessel to be completely inspected at Guam.

ACTION CONCERNING THE RECOMMENDATIONS

1. Recommendation 1 & 2:

1. That mandatory requirements for periodic inspection of selected areas of vessels which are not normally accessible to visual inspection and periodic inspection of specific shipboard operating equipment should be considered. Documentation of findings in such inspections should be centralized for ready access by inspection personnel. The information obtained could also be used to identify trends in the structural adequacy and reliability of equipment approved for shipboard use.

2. That hull plating and structural areas in way of cargo or vessel's stores, refrigerated spaces, and tanks or compartments which are covered by insulation be required to be exposed for detailed examination of the members at periodic intervals. Access for inspection should be specifically required in those areas where brine spills or condensation drainage can collect or where lack of ventilation can enhance deterioration.

Action: The Coast Guard is continually searching for methods of improving the commercial vessel inspection program. A computer based Vessel Inspection Information System is presently being designed that will predict inspection

needs and their locations from the history of the vessels, class of vessels and other related data determined at previous hull and equipment inspections. This system will be oriented toward anticipating problems rather than reacting to the consequences of materiel and personnel failures. The information will be available to the Coast Guard Marine Inspector prior to the arrival of the vessel for inspection. The VIIS program will be available on a test basis in 1977.

The Commandant does not concur that a specific periodic interval be established for the removal of insulation for inspection of inaccessible areas. The present regulations give the Coast Guard the necessary latitude to require the removal of insulation for inspection purposes. Circumstances vary considerably from vessel to vessel, making such a hard and fast rule unreasonable. The Coast Guard will issue amplifying instructions to field personnel alerting them to the consequences of brine and condensation accumulation in inaccessible areas of the hull. These instructions will reiterate the Coast Guard's policy to take whatever measures are necessary to insure that inaccessible hull areas, especially those showing signs of water or moisture accumulation, are fully and adequately inspected.

2. Recommendation 3: That cargo and miscellaneous vessels be required to meet damage stability criteria since the present classification rules for construction and assignment of load line appear to be inadequate in providing inherent protection from the adverse effects of extensive accidental flooding.

Action: The Coast Guard agrees that a damage stability criterion for certain cargo vessels would be desirable. A major decision necessary for development of such a criterion is the selection of a level of safety which will be effective and not overly restrict the flexibility of vessel design. Since the vast majority of vessels with which we are here concerned are oceangoing and on international voyages which are of a competitive (U. S. vs. foreign flag) nature, the Coast Guard has opened this subject at the Inter-Governmental Maritime Consultative Organization (IMCO), by placing this topic on the agenda of the Subcommittee on Subdivision, Stability and Load Lines. At the latest meeting of the Subcommittee, the Coast Guard presented the results of a recent research project on permeability of cargo holds. Such research is a necessary preliminary to setting a damage stability criterion. The Coast Guard next intends to suggest that calculations be required to show the capability of each cargo ship to resist flooding. This would provide the master with valuable information on the ability of his vessel to withstand flooding and will be another step toward international development and acceptance of a damage stability criterion.

3. Recommendation 4: That weathertight standards be required on all closures in the freeboard deck of the shelter-type vessels to preclude down flooding within the hull structure. If these closures by design or location within

cargo spaces will be inaccessible during the voyage, a requirement for their closure prior to loading or departure from the port should be considered. The Load Line Regulations should be amended to include a requirement for the closure of hatches in the freeboard deck when vessels are underway.

Action: The Commandant does not concur with this recommendation for several reasons. First, it does not address a circumstance of this casualty, since down flooding was not an apparent contributing factor. Second, the vessel was not truly an open shelter-deck vessel but was a closed vessel operating at a reduced draft, similar to that of a shelter decker, in which the primary means of repelling the entry of seawater is the tightness of the exposed weather deck. Since by regulation, 46 CFR 97.15-20, all exposed cargo hatches and other openings must be closed and made watertight there is little reason to do likewise with decks within the watertight envelope. Further, to do so would introduce a high and low zone for the restriction of flooding. In the event water was trapped in the high zone (shelter deck) a loss of stability would occur which would be detrimental in two ways, first the addition of high weight and second the free surface of the trapped water.

4. Recommendation 5: That standards be developed requiring a means of discharging water which may be introduced and confined above the freeboard deck of shelter-type vessels in a listed condition.

Action: The Commandant does not concur with this recommendation for the same basic reasons as stated in the preceding response. The bilge pumping system installed in the SS SILVER DOVE was not effective in discharging the sugar water mixture in the number three cargo hold. There is no practical means of dewatering the shelter deck area under the same conditions of list and cargo consistency.

5. Recommendation 6: That a recommendation be made to IMCO to modify the existing "Code of Safe Practice for Bulk Cargoes" to recognize the hazards associated with "dry" bulk cargoes in Appendix A when water is added.

Action: The Commandant concurs with the concept of this recommendation that recognition of the hazards associated with adding water to "dry" cargoes is needed. However, since the Code of Safe Practice for Bulk Cargoes is a publication based on intact stability, modification of the publication is considered inappropriate. The Coast Guard will, instead, recommend to IMCO (Subcommittee on Subdivision, Stability and Load Lines) that a resolution be adopted which would require that information regarding the dangers of shifting weights after damage be provided to the master.

Additionally, the Coast Guard will issue a Navigation and Vessel Inspection Circular regarding the hazards of shifting weights or counter flooding in emergency situations.

6. Recommendation 7: That consideration be given to including a motion sickness medication in lifeboats and liferaft survival equipment in view of the debilitating effects of motion sickness on the personnel and their consequent inability to function effectively while in lifeboats.

Action: The Commandant concurs with this recommendation. Motion sickness medication is presently required in liferafts fitted for ocean service. Regulations will be promulgated requiring motion sickness medication in lifeboats fitted for ocean service.

7. Recommendation 8: That disciplinary action under R.S. 4450, as amended, be taken looking towards suspension or revocation of the documents of crew members who were logged for their misconduct while in #1 lifeboat.

Action: Investigation under R.S. 4450, as amended, was initiated by the appropriate Officer in Charge, Marine Inspection.

E. L. PERRY
VICE ADMIRAL, U. S. COAST GUARD
ACTING COMMANDANT

DEPARTMENT OF TRANSPORTATION
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5943
9 April 1974

From: Marine Board of Investigation
To: Commandant (G-MVI)

Subj: SS SILVER DOVE, O.N. 250540; sinking in the North Pacific Ocean on 2 April 1973 without loss of life

FINDINGS OF FACT

1. At about 0244 (zone + 11), on 2 April 1973, the freighter SS SILVER DOVE, while enroute from Guam to the Panama Canal with a bulk cargo of raw sugar, sank in the north Pacific Ocean approximately 180 miles southwest of Johnston Island. The vessel had previously developed a hull failure behind the refrigerated space on the starboard side of the #3 lower tween deck. All attempts of the crew to restrict the ingress of water were futile, and the vessel proceeded to Guam where temporary repairs were made. Eight days after departing Guam, water was found coming in the adjacent frame space. While attempting to control the ingress of water from this new leak and correct a starboard list, the vessel developed a sudden 22-degree port list, at which time the crew, except for a nine-man salvage crew, abandoned the vessel. The SS SILVER DOVE remained afloat for a period of 41 hours, during which time the crew was rescued by the CGC NORTHWIND which was enroute from the Antarctic to Seattle, Washington. The CGC NORTHWIND subsequently took the crew of the SS SILVER DOVE to Honolulu, Hawaii.

2. Description of the SS SILVER DOVE:

Ex MORMAC SAGA

Official Number:	250540
Type Hull:	C3-SA-5
Home Port:	New York, N. Y.
Service:	Freight
Gross Tonnage:	7667
Net Tonnage:	4544

Length:	468.5 (Registered)
Breadth:	69.6 (Registered)
Depth:	29.5 (Registered)
Year Built:	1947
Where Built:	Ingalls Shipyard, Pascagoula, Miss.
Propulsion:	Steam Turbine
Horsepower:	8500
Document:	Permanent Register #28
Owner/Operator:	Oswego S/S Co., Inc. c/o Avon S/S Co., Inc. 3000 Marcus Avenue Lake Success, N. Y. 11040
Charterer:	Cargill, Inc., N. Y., N. Y. Type - Voyage Charter
Master:	Joseph L. Stone 83 Central Street Byfield, Mass. 01922 License #395399 Certificate Z-1184943
Last Inspection for Certification:	Date - 9 June 1971 Port - New York, N. Y.
Reinspected:	Date - 25 May 1972 Port - New Orleans, La.
Last Drydock Examination:	Date - 25 May 1972 Port - New Orleans, La.
ABS Surveys:	Annual classification survey, Special Periodical Survey No. 5 of hull and machinery, and annual load line. Date - 25 May 1972 Location - New Orleans, La.

Load Line	Tropical - 30' 00-1/4" draft Summer - 29' 05" draft

The SS SILVER DOVE was of a standard C-3 configuration with one deck house and five cargo holds (three cargo holds forward of the deck house and two aft).

The SS SILVER DOVE was a shelter deck vessel, the second deck being the freeboard deck; and the transverse bulkheads above the second deck were fitted with non-watertight tonnage openings. The upper tween deck was fitted with cargo side ports in #2, #3, #4 and #5 holds, both port and starboard. These side ports were double doors which opened outward and were dogged closed from the inside. A single door storing port opening inboard was installed on each side on the upper tween deck above the machinery space.

The #3 cargo hold (where the hull failure occurred) was the largest hold of the vessel, capable of accepting 147,330 cubic feet of bulk grain cargo. The lower tween deck of the #3 hold was fitted with four refrigerated cargo boxes. Boxes #3 and #4, accessible only from the square of the hatch, were located in the wings; two smaller boxes (#5 and #6) were located aft of the hatch opening. Diffuser (fan) rooms were located at the after outboard corners of the hatch. Inboard of the diffuser rooms and adjacent to the smaller refrigerated boxes were small lobbies which had inclined ladders providing access from the upper tween deck. The lobbies provided access to either the adjacent diffuser room or the adjacent inboard small refrigerated box (either box #5 or #6).

The two diffuser rooms in #3 lower tween deck extended from frame 96-1/2 to frame 102 (30-inch frame spacing), and were thus about 13 feet long and about 5 feet wide. The after boundary was the fuel oil settler tank; the outboard boundary was the insulated hull of the vessel. The hull frames were approximately 8" web x 4" flange configured with flange inboard and toe forward of the web. Marine plywood sheathing was attached to the inboard flanges of the frames; and the area between the hull plating and the sheathing was filled with insulation. The decks of the diffuser room and the reefer boxes were insulated and were built up about 14 to 18 inches above the steel deck. The deck insulation consisted of cork, a lead pan, and layers of concrete reinforced with wire mesh. The built-up deck extended outboard to the wood sheathing, creating a 14- to 18-inch-deep by 8-inch-wide trough between the wood sheathing and the hull plating. The starboard diffuser room, lobby and refrigerated boxes had a common drain line which emptied into a sump located below the deck of the lobby. A similar drainage system existed on the port side. The sumps were designed to empty into the engine room bilges.

The #3 lower hold was completely open except for a short centerline grain bulkhead which extended from the after transverse bulkhead forward almost to the square of the hatch. The bulkhead was fitted with limber holes at the deck level and a manhole opening for personnel access. The lower hold had a grain capacity of 89,400 cubic feet. The after transverse watertight bulkhead of #3 hold was offset 12' inboard of the shell with the center portion of the bulkhead extending 5' forward of the outboard portions.

The bilge system for #3 lower hold consisted of two bilge wells, outboard of the offset of the after bulkhead, which were recessed below the deck level into the double bottom tanks. The bilge wells were about 24" deep and were fitted with "high hat" box-like, dome type perforated strainers which protruded up into the lower hold and allowed liquids to flow into them. A short sounding tube for the bilge wells passed through the after bulkhead into the machinery space.

3. Deaths and Injuries: There were no deaths or reportable injuries resultant from this casualty.

4. Events Leading Up to the Casualty: The master reported aboard the SS SILVER DOVE on 2 December 1972 while the vessel was in New York Harbor. In his relief of the previous master, he was advised that the vessel was in satisfactory material condition. He inspected all cargo holds while they were empty and was satisfied that there were no abnormalities. Prior to the scheduled sailing, the vessel sustained boiler casualties which were repaired under Coast Guard and American Bureau of Shipping (ABS) supervision.

On 20 December 1972, the vessel sailed in ballast for Charleston, South Carolina, where 800 long tons of bagged Urea were loaded. The vessel then sailed on 22 December 1972 for Corpus Christi, Texas. While enroute, water, assumed by the master to be rainwater which collected in the open hold in New York, was pumped from lower #3 hold. In Corpus Christi, the SS SILVER DOVE was loaded to the summer load line with an additional 11,000 long tons of bagged Urea.

On 13 January 1973, the SS SILVER DOVE sailed for Saigon, Viet Nam, via the Panama Canal, with a departure draft logged as 29' 8" forward and 29' 00" aft. In Toboga, C.Z., 10,280 bbls. of bunkers were taken aboard. Departure draft from Toboga on 19 January 1973 was logged as 28' 5" forward, 31' 7" aft.

The westward voyage proceeded without incident until 25 January 1973. The weather had been making up for several days with the vessel shipping

seas on deck. Water was observed in the starboard engineer's storeroom in the upper tween deck area between #3 and #4 holds. The next day, water was discovered in the port and the starboard lobbies and diffuser rooms of #3 hold. Subsequent soundings of #3 lower hold indicated a rapid rise in water level, particularly on the port side. The port and starboard lobbies and diffuser rooms were not interconnected and water which accumulated on one side could not flow to the opposite side. Because water was observed dripping from ventilation ducting in the engineer's storeroom in the upper tween deck and the diffuser rooms, cargo vent trunks on the main deck outboard of and adjacent to the ship's superstructure were suspected as the source of the water. The intake trunks were about 6"x12" size and were located approximately 4 inches from the deck house. Inspection of these ventilation trunks disclosed that the blank cover on one was blown off because the holding bolts had wasted away and this vertical section of ducting was open, permitting water to enter when seas were shipped on the main deck. Inspection of the sides of the trunks next to the deck house also disclosed deterioration and some holes through which water could enter. Some of these ventilation systems passed through the engineer's storeroom and into #3 hold. Since these cargo vents were no longer required, a decision was made to crop them off flush with the deck when the weather permitted, and to seal the openings with welded plates. A total of six of seven deteriorated vent trunks were capped prior to arrival in Saigon.

Although #3 hold bilge wells were pumped every watch, the water in the hold could not be completely pumped out because, it was assumed by the officers, the bagged cargo acted as a dam and would allow water to seep into the bilge well only at a slow rate.

The vessel arrived in Saigon on 20 February 1973 and moored at buoy 11 in the harbor where the cargo was discharged into barges on both sides of the vessel. Water damage was found in the cargo in #3 lower hold up to a level of about 5 feet although the height varied dependent upon the location in the hold.

The master, chief mate and chief engineer were still concerned about the source of the water even though they felt it came from the ventilation system. The mate made several trips in a boat around the vessel to look at the hull but due to the barges alongside and the current, the inspection was rather cursory. The chief engineer also looked at the port side of the hull and the overboard clapper valves. He noted the clapper in the overboard valve to the port settler was wasted. This line was later blanked off from the inside of the hull.

The chief mate removed some sheathing and insulation in each of the diffuser rooms in #3 hold and in refrigerated box #4. No accumulation of

water was noted alongside the hull behind the sheathing. A thorough visual inspection of the interior of #3 hold was made. Water was noted dripping from the overhead of the after portion of the lower hold. The chief engineer reported that the entire after portion of the third deck was wasted. A pipe tunnel which passes longitudinally through #3 hold was flooded to test for leaks and found to be sound. No evidence of any source of water other than the ventilation system was found.

The exterior of the hull above the 16-foot waterline was painted by native workers while the vessel was in Saigon.

There were no known instances of any barge or boat striking the starboard side of the vessel in Saigon.

Prior to departure all holds were cleaned, including a washdown of the lower #3 hold to remove the residue of wet Urea. The SS SILVER DOVE received 2674 bbls. of bunkers on 27 February 1973 and sailed for the Philippines on 4 March 1973. The departure draft recorded was 9' 06" forward and 19' 06" aft.

The vessel arrived in Batangas Bay, Philippine Islands, at 0742 local time on 7 March 1973, and anchored awaiting a berth at the fueling dock.

While at anchor, the first assistant engineer installed two 1-1/4"x4" extra heavy pipe nipples in the bulkhead between the #3 lower hold and the machinery spaces about 1-1/2 inches above the double bottom tank tops to provide an additional check for water in #3 lower hold. The nipples were threaded and capped in the machinery space and welded flush to the bulkhead in the cargo hold. Because they were installed in the offset portions of the bulkhead, the drain nipples were transversely situated.

At 1048, 8 March 1973, the vessel shifted to the Caltex Fuel Pier, mooring portside to the dock. While the vessel was fueling, the cargo surveyors boarded the vessel to inspect the holds and determine their readiness to receive cargo.

At 0847, 9 March 1973, after having received 8043 bbls. (1072.4 L/T) of fuel and 266 L/T of fresh water, the SS SILVER DOVE shifted to the Batangas Bay Terminal, the sugar loading pier, mooring portside to the dock. During docking, the vessel's port bow struck a concrete dolphin. An ABS surveyor was called for an examination and reported no damage to the vessel.

The cargo surveyors required certain items be accomplished in preparation for loading the sugar, among which were:

a. All wooden hatch boards were to be removed and stowed in the wings of the holds;

b. All cargo hold deck drains below decks were to be cemented closed;

c. Bilge strainers in all holds were to be covered with burlap and cemented around the periphery to prevent sugar from getting into the bilge wells;

d. Two minor oil spillages in the vicinity of fuel oil vents in hatches #3 and #4 were to be cleaned and wiped dry;

e. A wooden box approximately 2'x2' was to be fabricated around the fuel oil vent in the after starboard corner of #3 lower hold where a spill had occurred on 9 March while taking bunkers.

A source of the oil in the #4 hold was determined to be a wastage of the vent, serving #5 starboard double bottom, at the upper tween deck level.

The one remaining holed vent trunk by the forward deck house was cropped and capped with a welded plate prior to loading.

At 1200, on 10 March 1973, loading of #2 hold commenced. The chief mate had been given a stowage factor for the sugar of 41 cubic feet per ton. Draft before loading was 9' 09" forward and 22' 09" aft. The vessel had o board approximately 1717.4 long tons of fuel and 478 long tons of fresh water. A total of 10,300 L/T of cargo, according to shore measurement, was loaded in the following sequence:

1200, 10 March - 0045, 11 March	#2 hold	1115 L/T
0415, 11 March - 1245, 12 March	#3 lower hold	1640 L/T
2015, 12 March - 1930, 13 March	#4 hold	1198 L/T
2145, 13 March - 0115, 14 March	#5 hold	1032 L/T
0315, 14 March - 1530, 14 March	#3 hold	1262 L/T
2030, 14 March - 1600, 15 March	#1 hold	2814 L/T
1750, 15 March - 0430, 16 March	#5 hold	1239 L/T

Trimming crews were used in all holds to fill the underdeck void spaces which could not be reached by the mechanical loader.

During the loading period, no rain had fallen and the raw sugar had been stowed under cover. All weather deck hatches were effectively secured, using pontoons covered with three or four canvas tarpaulins secured by battens, cross-battens and wedges to keep the canvas in place.

Final loaded draft was logged at 27' 02" forward, 32' 02" aft. However, the loaded draft as recorded by personnel at the sugar terminal was 30' 01" forward, 30' 00-1/2" aft and 30' 00" amidships. No fresh water allowance is applicable. The vessel had about a 3-degree starboard list. Stability calculations by the chief mate made on the stabilogauge indicated a metacentric height of 3.4 feet upon sailing and 1.6 feet projected for arrival at the Canal Zone.

The liquid loading of the ship's tanks as recalled by the chief engineer was as follows: #1 port and starboard double bottoms - full; #2 port and starboard double bottoms - 500 bbls. each; #3 port and starboard double bottoms - full; #5 port and starboard double bottoms - full; #6 port and starboard double bottoms - full; and the after peak tank was full. All #5 deep tanks and both settlers were full. The foregoing tanks all contained fuel. No. 4 starboard double bottom was empty; #4 port double bottom had about 130 tons of water; the forepeak was being pumped out at departure, and all #4 deep tanks which were used for ballast were empty at sailing. Feed water and potable service tanks had about 59 tons total. The remainder of the fresh water taken aboard at the fuel pier had been used for flushing tanks and was pumped overboard.

The SS SILVER DOVE sailed at 0800, 16 March 1973, for an undesignated Gulf Coast or East Coast port of discharge via the Panama Canal with a speed of advance of 14 to 14.5 knots.

Shortly after sailing, a routine fire and boat drill was held. The log indicates that both the engine in the #1 life boat and the fleming gear in the #2 life boat were operated.

The diffuser rooms in #3 hold were checked and found dry.

The weather experienced during the next five days was winds force 4 to 5 from the northeast with a moderate swell.

At about 1800, 17 March 1973, the chief mate went into #3 hold diffuser rooms to inspect those areas and found the port diffuser room and lobby dry, but found water on the deck of the starboard lobby. Entering the starboard diffuser room, he found the area where sheathing had earlier been removed to have filled with water up to the built-up deck level. The chief mate searched for the source of the water. Placing his hand under water by frame 100, he felt water flowing in through the hull plating. He immediately notified the master and chief engineer and they came to the scene. Initial attempts to remove the water with a bucket were unsuccessful so the general alarm of the vessel was sounded and all hands turned to forming a bucket brigade up the ladder. On inspection, an 8" hull failure, variously described as either a series of small holes or a crack, was discovered 8" above the steel deck. The crack was generally horizontal, centered on frame 100, and it passed through a half

round scallop in the frame.

The chief mate made a patch out of rubberized material backed by 2x6 planks wedged in place with steel wedges. He then poured concrete around this patch, which effectively reduced the water flow to the point where the bucket brigade was able to remove most of the water from the area. The work was completed by midnight. It was the opinion of those present that some of the water entering the diffuser room was flowing into the #3 lower hold through the previously noted wasted deck area in the after end of the 3rd deck.

The next morning, 18 March, the weather was still moderate with force 4 to 5 winds. The vessel pitched and rolled moderately in the seas. It was apparent that the patch aft of frame 100 was inadequate although that forward of the frame seemed to be holding. More sheathing and insulation were removed, exposing the frames on either side and up to about four feet in height. The concrete patch aft of frame 100 was torn out and replaced with a canvas bag filled with "duck seal" (pliable putty), which was shored and wedged into place. The drain line connecting the starboard sump tank with the engine room was clogged by debris from the removed insulation. As a result, water flowing from the refrigerated spaces into the sump tank could not be emptied into the engine room. The sump tank was pumped out using a small portable air driven pump with a capacity of approximately 15 gallons per minute; however, due to a limited supply of ship's air, this pump could operate only for 15 minutes at a time.

The master sent a message to the owner advising that the SS SILVER DOVE had sustained an 8" crack at the 24-foot draft level, frame "99" (sic), plate SG-12, and inquiring about diverting to Guam for repairs.

On the evening of 19 March, an engineering watch officer routinely removed the cap from the starboard nipple in the forward bulkhead of the engine room to check for water. A stream of granular sugar under pressure was forced out of the nipple followed a few minutes later by a strong stream of brown water shooting out some 15 feet. The force was such that the cap could not be replaced on the nipple and the flow continued for several minutes, then stopped. Later, a valve was put on the nipple to replace the cap so any reoccurrence could be controlled. Although small flows of sugar or syrup were later encountered, no flow under high pressure was again noted. On one later occasion, granular sugar flowed from the starboard nipple for several hours. No flow of cargo or liquid was ever encountered from the port nipple. The sugar on the port side, as sampled through the nipple, was found to be of the same consistency as when it was received in Batangas.

During the next two days, water continued to flow in through the crack in spite of the patches. A new cement patch was applied. The vessel was stopped twice in an unsuccessful attempt to place a canvas patch on the outside of the hull to be secured with lines passing under the hull. When the vessel was dead in the water, the flow rate through the crack decreased. Another repair considered was to bolt a 27"x10" steel plate over the crack on the outside of the hull. It was envisioned that this plate would have two studs welded to it which would pass through holes to be drilled from the inside of the hull, 13 inches either side of frame 100. An attempt was made to drill one of the holes with a new 5/8" bit and air drill but it was unsuccessful because, as the master related, "The hull in that area . . . was so sound."

Further messages were exchanged with the owner indicating the inability to stop the flow of water through the crack. In a message sent about noon on 19 March, the owner was advised the crack had enlarged. This enlargement was later described as a widening rather than a lengthening of the crack. Personnel noted that syrup was being pumped from the #3 starboard bilges. Consent was given by the owner to divert to Guam, where the vessel would be met by an independent marine surveyor to represent the owner.

The SS SILVER DOVE arrived in Guam at 0912 (local time) on 21 March 1973 and anchored in Apra Harbor. The draft upon arrival, which was routinely taken by Coast Guard personnel, was 28' 10" forward, 30' 06" aft. At about 1200, a representative of the Dillingham Corporation ship repair facility of Guam boarded the SS SILVER DOVE. The vessel was on an even keel at the time. He went down to the diffuser room in company with the vessel's personnel, where he saw approximately 6 inches of water over the built-up deck. Shoring was in place over an area immediately adjacent to frame 100. The shoring forward of frame 100 was removed so that he could examine the area of the crack. As he placed his hand under water he could feel "a very decided flow of water coming in," which seemed to be directed downward rather than normal to the skin of the vessel. Sunlight coming through the crack fell on his hand as he placed it underwater to examine the crack. The reflection of the sunlight seemed to mirror a series of holes rather than a continuous crack. The crack ran essentially horizontal, the upper edge of the plate being offset slightly inboard of the lower edge. Some flow of water was also coming out of the crack aft of the frame. The patch was replaced. The Dillingham representative prepared a drawing of his observations and departed the vessel.

During the day, while awaiting the arrival of the owner's surveyor, the

#4 port aft deep tank was ballasted to give the vessel an approximate list of 6 degrees to port, thereby raising the crack closer to the surface of the water.

The master, chief engineer, and first assistant engineer entered the water without using face masks or swimming goggles and placed a piece of plastic, held in place by magnets, over the crack to reduce or stop the ingress of water. Neither the master nor the chief mate noted anything unusual about the condition of the plating around the crack. The first assistant engineer did feel a slight indentation in the hull plating in the area of the crack.

At approximately 2015, the owner's surveyor, who had just arrived from San Diego, the Dillingham production superintendent, the vessel's agent, the Commanding Officer, Marine Inspection Office (OCMI), Guam, and a junior Coast Guard officer came aboard. They went directly to the master's cabin where they talked briefly about the casualty and then went down to the starboard diffuser room.

The sheathing and insulation had been removed from about 6" forward of frame 99 to 6" aft of frame 101 and from the steel deck level to a height of four feet. A small amount of water was noted in the area between the built-up deck and the hull. A section of frame 100 from the deck to a height of approximately 22" had been removed. A steel plate approximately 12"x8" was jacked against the hull with a gasket seal, which effectively stopped the flow of water.

The patch was not removed for the inspection; however, the OCMI was satisfied with the description given him of the crack and did not desire to cause any more flooding.

The inspection personnel returned to the master's cabin where the type of repair to be made was discussed. Since there were no commercial dry-docking facilities at Guam, a temporary repair consisting of a concrete patch inside a fabricated steel box between frames 99 and 101 was proposed and accepted by all.

The parties discussed the possibility of drilling the ends of the crack to prevent enlargement. The fact that the drilling would have to be done below the existing waterline, thereby admitting more water into the vessel, was a primary influencing factor in the decision not to drill the ends of the crack. Also, the consensus was held not to disturb the hull plating in the area because it was considered wasted. The fact that the

crack was horizontal instead of vertical and was approximately at the neutral axis of the hull girder influenced the OCMI to believe it was a localized deterioration rather than a stress fracture.

The vessel's agent, the Dillingham superintendent, and the two Coast Guard officers departed about 2115 hours.

At 0845, 22 March, the shipyard workers and the Dillingham production supervisor came aboard, and took over the task of effecting repairs.

Two scuba divers from Trident Diving Company engaged by Dillingham Company arrived at about 1000 hours that morning. The divers were directed to locate the crack and to put a temporary patch over it to prevent water from entering the vessel during the construction of a concrete patch inside. The divers entered the water in the late morning and located the crack, which initially appeared to extend only about 10 inches in the vicinity of the area where two magnets were previously placed. However, as they scraped and chipped rust off of the side of the vessel to effect a good seal, they found that the crack extended further forward so that the total length appeared to be approximately 14 inches. The crack appeared to start at a dent in the shell plating of the vessel which was about 4 inches long, an inch deep, and several inches from top to bottom. The widest point of the crack was in the indented area where it was opened approximately one quarter of an inch. The crack then tapered down as it went forward into a hairline crack. The divers sealed the crack with lead wool covered with a putty-like substance. They also noted about four or five inches below the crack a wasted area which appeared to be a four- or five-inch section of horizontal weld missing from a seam. The shell expansion plan does not indicate a plate seam in this area. No water appeared to flow through this wasted area. However, the divers plugged this area and reported to the Dillingham supervisor and the owner's surveyor concerning what they had observed and done. There was no discussion between the divers and any of the repair or supervisory personnel about the length of the original crack which they observed on the exterior of the hull.

During the morning, the local nonexclusive ABS surveyor came aboard and examined the area of repair. The ABS surveyor made no further requirements. An ABS report of survey verifying the inspection was subsequently sent to the owner requiring the area to be examined at the vessel's port of discharge by a surveyor and dealt with to his satisfaction.

In preparation for fabricating the steel box enclosure which would hold the concrete patch, the water in the diffuser room was removed and the remainder of the 22" section of frame 100 was cropped, leaving less than 1/8" protruding from the shell plating.

The owner's surveyor observed about a 10" crack 8-1/2" above the steel deck. The hull plate in that area appeared wasted to him, with about 3/8" thickness of scale between frames 99 and 101 and some pitting. He did not observe any indentation of the plate in way of the crack. The plate was lightly cleaned and scaled to obtain a good seal over the crack. The steel deck did not appear to be as heavily wasted as the hull plating. Shipboard and other shoreside personnel noted varying degrees of general deterioration and pitting. The OCMI observed heavy deterioration from the top of the insulation removal to the deck, centered on frame 100, and increasing in width as it approached the deck. Other areas of the plate near frames 99 and 100 appeared in good condition and a coating of adhesive preservative was still visible.

The shipyard supervisor observed the exposed shell plating had slight scale, rust, and pitting the size of a dime or quarter which were about 1/16" to 1/8" deep. This condition was present over the entire area of exposed plating. He stated the hull plating was not cleaned.

Frames 99 and 101 and the steel deck were scraped and cleaned where welding would be done. Portions of the built-up insulated deck in the area of the patch were also removed.

Two 2"x4"x1/4" horizontal channels were welded between frames 99 and 101. A vertical angle was welded between the two channels midway between frames 99 and 101. A section of 1/8" steel plate variously described as 6"x6", 8"x12" or 26"x10" covered with Red Hand sealant and a 1/4" rubber gasket were put against the skin of the vessel over the crack and shored into place with steel wedges. Two pieces of 5/16" steel plate were then welded from the frames to the center vertical angle. These plates were also welded to the deck and the horizontal channels and were flush with the toe of the frames. A steel enclosure measuring 60" wide, 2' high and 8" deep was formed with an open top which was bounded by the steel third deck, frames 99 and 101, the hull plating and the steel plates between the toes of the frames.

At midday, the OCMI returned to the SS SILVER DOVE and examined the steel box which was being fabricated and noted that a steel plate with gasket was placed against the hull plating over the crack. Shortly thereafter, he left the vessel.

Concrete, utilizing bagged Portland cement and coral sand from the local concrete plant, was mixed on deck and the first pour of about 1 foot in depth was made at 1700 hours. The OCMI returned aboard at approximately 1845 and inspected the patch which at that time was being filled with concrete almost to the top of the form. The OCMI issued a CG 835 requirement that permanent repairs be made prior to 1 June 1973. The OCMI and the Dillingham superintendent left the vessel at about 1900 hours.

Prior to leaving, the OCMI requested that the master delay sailing until

after midnight so that the concrete would have an opportunity to set up. Repair personnel estimated it would take 6 to 8 hours for the concrete to set. The concrete form required more material than was originally estimated and the final pour was made at about 2100, after additional material was received from shore. Having completed their work, repair personnel left the vessel at about 2140.

The SS SILVER DOVE sailed from Guam at 0048 on the morning of 23 March 1973. The recorded sailing draft was 27' 04" forward, and 30' 06" aft. No stability calculations were made. No. 4 port aft deep tank was partially deballasted to remove the port list prior to sailing, leaving approximately a 5'6" sounding.

The liquid loading of the tanks, as recalled by the chief engineer, was: forepeak, #1 double bottoms, and #2 double bottoms all empty; #3 double bottoms full; fuel oil settlers full; #4 port double bottom 130 tons (water); #4 starboard double bottom empty; #5 port double bottom 1000 bbls.; #5 starboard double bottom 960 bbls.; #6 double bottoms full; #2 deeps empty; #4 deeps empty; #5 port deeps full; #5 starboard deep (forward) 700 bbls.; #5 starboard aft deep 50 bbls.; and aft peak full. There were also approximately 22 tons in each potable water tank and 15 tons of feed water. This liquid loading had been accomplished by selective burnout of the fuel in order to maintain the vessel on an even keel.

The wind was from the east, building up from a force 4 to 6 during the period of the day. Seas were moderate, with the vessel pitching and rolling moderately while proceeding at full speed on an approximate due east course heading into the swells. At 0430, the second mate on watch had the patch inspected and reported to the master that a small amount of water was flowing out between the hull and the top of the patch. That evening, the master checked the patch and found it to be solid. However, a dribble of water was observed coming out of the top of the concrete as the hull appeared to pant in the area of the patch. The caps on the nipples through the after bulkhead of #3 hold were removed and on the 23rd there was no indication of water.

On Saturday, 24 March, the winds remained from the east at about force 6 and the vessel proceeded easterly, heading into the seas, pitching and rolling moderately.

On 25 March 1973, the wind continued from the east at force 6 to 7. The vessel pitched moderately to heavily in the rough easterly seas and large swells.

On 26 March, the wind continued from the east at force 6 to 7 with the vessel pitching moderately while proceeding easterly into the swells. The soundings of the #4 port aft deep tank to 6'1" was logged. No. 4 port forward deep tank showed a sounding of 21". The vessel had developed a slight starboard list.

On 27 March 1973, the wind increased slightly to force 7 from the east with the vessel pitching heavily in a northeasterly sea and swells. The master, chief engineer and chief mate discussed how best to remove a starboard list of approximately 5 degrees which the vessel had gradually acquired. The chief engineer preferred not to move any oil so the chief mate fully ballasted the #4 port aft deep tank to 18' 06". At 1935 (zone - 11), the vessel experienced a machinery casualty to the #3 forced draft blower motor and it was necessary to reduce the speed from 13 knots (79 rpm) to 40 rpm while the motor was replaced.

On 28 March, the wind moderated to force 5 from the east and the vessel was pitching and rolling moderately in head seas. The log book indicates that #4 port forward deep tank had a sounding of 3', an increase of 1-1/2' from the previous day; and #4 starboard forward deep tank had a sounding of 3-1/2', an increase of 2-1/2'. The cause of the changes in soundings was undetermined.

At noon, when shifting fuel oil suction from the port to the starboard settler, the vessel lost fires in both boilers due to water in the fuel oil. Fires were restored in the boilers and the vessel got underway again at 1300, making 50 rpm as repairs continued to the forced draft blower motor. The source of the water in the starboard settler was not immediately identified. However, the last transfer of fuel was taken from the #3 starboard double bottom. Two 300-bbl. draws of fuel had been taken from #3 starboard double bottom tank and soundings indicated the tank was down only 300 bbls. instead of the expected 600 bbls. The tank was checked and water was found in the tank although the manner in which water entered #3 starboard double bottom could not be identified.

The chief mate, in checking the starboard diffuser room, found a little more water bubbling up at the top of the patch between the hull plating and the concrete. The mate wedged small pieces of wood between the concrete and the plating and caulked the area with a plastic sealant. Shoring was placed in position to hold the caulking, and the inflow of water was almost eliminated.

At 0830 (zone - 12), on 29 March, repairs were completed to the forced draft blower and the vessel increased speed to about 12 knots (70 rpm). Soundings logged at noon indicated the #3 hold starboard bilge well was

being pumped. The weather started to make up, with the wind backing slightly to east-northeast and increasing to force 8 to 9. The vessel encountered large swells and shipped broken seas over the port bow. Course was changed at 1400 hours from 105°T to 077°T. A routine fire and boat drill was conducted, at which time #1 lifeboat engine was run for 5 minutes.

The following morning, the SS SILVER DOVE crossed the International Date Line and logged a second 29 March (Meridian Day). Inspection of the starboard diffuser room, lobby and inboard adjacent refrigerated box disclosed an increased accumulation of water. The lobby had 8" to 10" of water over the deck. The water in #5 refrigerated box apparently was entering by way of the drain common to the starboard refrigerated spaces in #3 lower tween deck. The vessel's personnel were turned to breaking out additional areas of the built-up deck of the diffuser room and removing sheathing and insulation from the hull between frame 101 and the after bulkhead in an attempt to locate the source of the increased flow of water. Oil sludge was found on the deck behind the insulation in the after outboard corner of the compartment, indicating a possible wasted vent line from a fuel tank. The fuel oil vent line for #3 starboard double bottom was found behind the sheathing between frame 101 and the after bulkhead. A portable air-driven pump was utilized in removing water from the drain tank under the lobby into which these compartments drained. At noon, the deck log indicated the starboard bilge of #3 hold was being pumped and the #4 starboard aft deep tank had an unexplained sounding of 5'3". The vessel still had about a 5-degree starboard list. Weather during the day continued rough, with large swells and seas being shipped as the vessel rolled and pitched heavily. Gale winds, force 8 to 9, continued throughout the day from the east-northeast. Course was changed to 082°T at midday.

On Friday, 30 March 1973, the same weather conditions prevailed and the vessel continued to ship seas over the bow and on the main deck as it pitched and rolled heavily. A starboard list of about 5 degrees was noted. The master and chief engineer discussed methods of recovery of the fuel remaining in #3 starboard double bottom and decided to transfer some of the fuel and water to the starboard settler where heat could be applied to separate the water and fuel. The water could then be drained from the bottom of the settler and the salvaged oil transferred to #5A port deep tank. This operation had to be done several times because of the limited capacity of the settler (400 barrels). By 2130, about 400 barrels of recovered oil had been processed and transferred to #5A port deep tank.

During this day, a new hull leak was discovered between frame 101 and the

after bulkhead in the starboard diffuser room when the sheathing, insulation and decking were removed in that area. This new defect was characterized as pinholes in the hull plate through which water could be felt flowing, or as an intermittent crack some 14" to 16" long. The defect was in approximately the same horizontal plane as the previous crack and was not visible during the inspection since it was located under water. One area of the hull plating through which the water was felt to flow was slightly aft of frame 101 and another was near the after bulkhead behind the fuel oil vent line. The fuel oil vent line was found to be heavily deteriorated near the deck and had a small hole on the outboard side located some 2" above the steel deck into which water was flowing. This was considered to be the source of the water which had contaminated the fuel in #3 starboard double bottom.

During the afternoon, the chief mate patched the hull plating with canvas bags filled with duck seal, but he did not consider the patches very effective. The air pump was used intermittently and could keep up with and at times ahead of the water flow which entered into the starboard diffuser room. That evening, the chief mate informed the chief engineer the duck seal patches were not holding. The chief engineer fabricated a 12"x18"x3/8" steel plate with rubber gasket material fastened to it to patch the area. The duck seal patches were removed and the plate placed behind the vent and jacked against the hull plating. No water could be felt flowing in through the hull plating when the patches were changed although the chief engineer did feel with his hand what he characterized as a crack near the steel decking. The water was about 2 feet deep (above the steel deck) in the area of the new crack. Even though he could not identify the source, the chief engineer felt that the flow of water along the outboard edge of the compartment was coming from somewhere other than the area he had just patched. The concrete patch did not appear to be the source.

The vent line to #3 starboard double bottom was hacksawed above the water level in the diffuser room before leaving the area for the night. It was anticipated that it would be cropped at the steel deck level the next day so the water entering the hull would freely drain to the #3 starboard double bottom tank from which it would be pumped overboard.

The portable pump, which operated only intermittently, no longer had any effect on the water level. In spite of the obvious flow of water into the compartments, the level did not increase appreciably. The vessel's personnel felt the water was probably flowing into the lower hold.

The vessel's officers worked in the diffuser room until about midnight. The officers were exhausted and, although they realized that water was still flowing into the vessel, they left the diffuser room with the intention of making further examination and temporary repairs the following morning. The air-driven drain pump was secured.

During the night, the fuel in #5 port forward deep tank was transferred to the #5 port and starboard double bottoms and the remaining contaminated fuel (about 800 bbls.) from #3 starboard double bottom was transferred to the #5 port forward deep tank.

The watch engineers had been instructed to sound the bilges of #3 hold every watch and to pump them if warranted. The bilge piping to the starboard bilge well was clogged with residue from a previous cargo of bulk corn carried on a previous voyage. Pumping of the starboard bilge well was done through a hard rubber hose connected between the sounding tube and the bilge pump suction. This arrangement worked satisfactorily. Pumping of the bilge wells in #3 hold took no more than 15 minutes and the liquid found in the bilge wells varied and was described as either a thin or thick syrup. The maximum sounding noted in the #3 starboard bilge well was 18" shortly after the first hull crack was discovered.

In the early morning hours of 31 March 1973, the weather abated. The wind dropped to force 6 and the seas moderated so that at 0800 only spray was being taken on the main deck. The vessel was proceeding at a speed of about 11.4 knots. A 3-degree starboard list was observed shortly after midnight. At 0630, transfer from #3 starboard double bottom was complete. A 2-degree starboard list was noted on the bridge at about 0700.

The master arose at 0700 and went to the chief engineer's office, where he sat having coffee and waiting for the chief engineer to get up. At about 0800 he returned to his office to do some work at his desk.

Shortly before 0800, the third assistant engineer relieved the engine room watch officer. The engine room logbook indicated that the previous watch had pumped the #3 hold bilge wells. A check of the soundings shortly after 0800 showed 5" in the port bilge well and 7" in the starboard bilge well, which was not sufficient to warrant pumping. The bilge pump was lined up to take suction on the shaft alley to remove 4' or 5' of bilge water. No other transfer of liquids was taking place. At approximately 0815, the watch officer noted the rate of water dripping from the deck above #1 generator had increased and he called the chief engineer in his room to report the change. This generator had been covered with canvas when the leak was first noted. The engine room clinometer showed the vessel on an even keel at about 0830.

The liquid distribution at this time as recalled by the chief engineer was:

Forepeak - empty	
#1 port D.B. - empty	#1 stbd D.B. - empty
#2 port D.B. - empty	#2 stbd D.B. - empty
#3 port D.B. - full	#3 stbd D.B. - empty
#4 port D.B. - 158 tons	#4 stbd D.B. - empty
#5 port D.B. - full	#5 stbd D.B. - full
#6 port D.B. - full	#6 stbd D.B. - full
#4A port deep - 18 ft., 6 in. (380 tons)	#4A stbd deep - 3 ft., 6 in.
#4F port deep - 3 ft.	#4F stbd deep - 2 ft., 3 in.
#5A port deep - full	#5A stbd deep - full
#5F port deep - full	#5F stbd deep - full
Aft peak - full (F.O.)	Settler port - 59 tons
All #2 deeps - empty	Settler stbd - 59 tons

The engineering watch officer awakened the chief engineer at 0815 to report the increased dripping of water over the generator. The chief engineer dressed and went to the engine room. While he was there, the dripping stopped. He noted there was very little list and that the vessel was not rolling as much as the previous day. The chief engineer talked with some of the watch personnel and went up to his office.

At about 0845 or 0900 the chief mate awoke. He noted the day was clear and the vessel felt good. There was no list and little roll. He lit a cigarette and sat down at his desk.

The condition of the patch or the degree of flooding in the starboard diffuser room was not checked by any crew members during the night or morning hours. There is no evidence that anyone went below to look at the starboard diffuser room after midnight.

On the bridge, the third officer relieved the watch about 0800 and noted the vessel was on an even keel. The third mate took his first sun line about 0825. He went out to take his second sun line at about 0925, when he felt a sensation of the vessel starting to list to port.

The chief engineer shortly before had also felt the vessel slowly starting to list to port and was called by the watch engineer, who had noted the change in list and was alarmed. The chief engineer ran up to the master's room.

The master, who had been working at his desk, realized he was leaning further over his desk because of the developing port list and headed for the bridge. He met the chief engineer in the passageway. Each inquired of the other as to what was happening. The master ordered the chief engineer to pump #4 port after deep tank overboard and to stop the engine. He then ran to the bridge, and ordered the rudder placed 15 degrees to each side. The SS SILVER DOVE responded sluggishly and continued increasing the list to port. The third mate, looking at the clinometer, told the master the vessel was passing 15 degrees and the master rang up stop on the engine order telegraph and sounded the general alarm to get everyone up on deck.

The chief mate, sitting in his room, felt the vessel "lurch" to port and heard the vessel's general alarm sound as he ran to the bridge. The master ordered an SOS broadcast, giving the SS SILVER DOVE's position as 13° 50' North, 170° 30' West. At 0937 the third mate noted the vessel was steadying at about 22 degrees port list, with rolls ranging between 12 and 27 degrees to port. The master ordered the chief mate to lower the lifeboats on the tricing pendants.

In the meantime, the chief engineer had called the engine room and told them to start deballasting #4 port after deep tank. He then went down to the engine room. The main turbine had been stopped when he reached the floor plates. The generator failure alarm was sounding. The bilge pump suction had been shifted from shaft alley bilges to the #4 port after deep tank. Because of the list, great difficulty was encountered in moving about the engine room. Before anything of consequence was done in the engine room, the abandon ship alarm sounded and the chief engineer secured the fires in the boilers. A second electric driven pump was lined up to deballast the #4A port after deep tank. The engine room was evacuated with all machinery except the boilers left in operation. No water other than normal bilge water was noted in the engine room. As the steam pressure dropped, the machinery, including the deballasting pumps, stopped and the generators tripped off the board about 15 to 30 minutes after the crew left the engine room.

When the list reached 22 degrees, the master ordered most of the crew to leave the vessel. Because of the design of the gravity lifeboat davits, the master was concerned over the ability to launch the lifeboats after a 15-degree list was reached. During the launching process, the electrical power to the winch failed and the crew raised the boat by use of the hand crank to free it from the davit hook. During the lowering process, the starboard boat became fouled on the deck rails. With the use of planks, the boat was freed and was successfully launched. The

launching was synchronized with the vessel's starboard roll to take advantage of the favorable roll reducing port list. No. 1 motorboat, with 21 people, was launched at 0955 with the second mate in charge; and #2 boat, with 10 people, was launched at 1010 with one of the third mates in charge. Swells at the time were about 8 foot. Nine persons (the master, chief mate, one third mate, chief engineer, first assistant engineer, both third assistant engineers, boatswain, and an able seaman) remained aboard as a salvage detail for possible relighting of the plant and damage control. In order to keep the lifeboats near the vessel, three lines were tied together to form a 900-foot line, buoyed with life rings, to which both lifeboats were secured as it trailed to windward from the vessel. Communication between the vessel and the boats was conducted with portable radios. When the radio officer abandoned the vessel, he left the radio auto-alarm activated on 500 KHz to assist rescue units in obtaining RDF bearings.

Aboard the SS SILVER DOVE, the chief engineer manually started the emergency generator, which ran for awhile but then developed fuel problems. The chief engineer attributed this to the fuel outlet being on the starboard side of the fuel tanks which, because of the list and roll, caused it to lose suction. The generator was not needed during the daylight hours and was not restarted to conserve fuel.

5. Rescue Phase: The SOS broadcast by the SS SILVER DOVE was heard on 500 KHz at 0947 (zone + 11), 31 March, by the U. S. Coast Guard Cutter NORTHWIND which was at position 10° 10' North, 169° 52' West, enroute from the Antarctic to Seattle, Washington. The vessels were about 225 miles apart and the CGC NORTHWIND diverted to the distress scene, increasing speed to 13 knots. The operational control of the CGC NORTHWIND was shifted from Commander, Pacific Area, to Commander, 14th Coast Guard District. Another vessel, the British tanker SS ARIANTA, also responded to the SOS and diverted to the scene. Coast Guard aircraft CG 1340 from the Air Station, Honolulu, was launched and arrived on scene at 1350 (zone + 11), locating the SS SILVER DOVE at position 14° 06' North, 170° 19' West.

Between 1300 and 1330, the master of the SS SILVER DOVE decided to send two of the salvage party, the third mate and one of the third assistant engineers, into the boats. The boats were contacted on the portable radio and were directed to come alongside. The engine of #1 boat, which had run well originally, failed, reportedly because of a dead battery; and could not be restarted with the hand crank. In boat #2, the men had difficulty coordinating the fleming gear, either due to lack of experience or malaise as most of the crew members in both boats were seasick in the rough sea with 7- to 8-foot swells. Some of the crew were apprehensive about going

alongside the vessel for fear it would capsize or that the lifeboat would be damaged by the seas against the side of the vessel. The pick-up of the two officers was effected by #1 boat, which came alongside the starboard side (windward). The third assistant engineer, wearing a life-jacket, climbed down a jacobs ladder, entered the water and was picked up a few minutes later. The third mate followed him into the water, but the boat and vessel drifted away from him. The third mate finally reached the 900-foot line trailing from the vessel and hung on until he was picked up approximately 25 minutes later by #1 boat. Two crew members in #1 boat were logged for disobedience of the second mate's orders for refusing to row back to the ship.

The aircraft overhead was unable to establish communications with the vessel and dropped three portable radios. The parachute on the first one did not collapse when it hit the water and it was blown away. The second radio was dropped too far away and the third was lost because the boat crew was too exhausted from rowing to pick it up.

On the SS SILVER DOVE, at 1327 hours, the master, a licensed amateur radio operator with knowledge of morse code, successfully communicated with the CGC NORTHWIND on 500 KHz, indicating that the SS SILVER DOVE was taking on water in the holds and bunker tanks. In answer to an inquiry concerning a tow, he expressed doubt that the vessel could withstand a tow in bad weather.

The persons remaining aboard secured all watertight doors and port holes on the main deck except for one port hole in a locked room on the port side. Waves were coming over the deck edge on the port side as the vessel rolled in the sea and swells.

All persons remaining aboard stayed on the stern. A slick of sugar and oil which formed to windward during the day appeared to be coming from the port side of the midships area. During the evening, the able seaman went into the upper tween deck area between hatches #3 and #4. There was no evidence of flooding or sugar on the port side. The engine room was free of water and was not flooding. During the night, the master timed the period of the rolls with a stop watch and found them to be 11 seconds. He was of the opinion that the vessel was gradually sinking deeper in the water.

At 1800, Coast Guard Aircraft 1340 deployed a data marker beacon transmitting on 240.6 MHz. At 2022 hours, Air Force Rescue Aircraft 50991 relieved the Coast Guard aircraft as On-Scene Commander.

After dark, flares were periodically dropped. The weather continued to moderate slightly. The CGC NORTHWIND sighted these flares at 0129, 1 April 1973, and assumed On-Scene Commander at 0235 after identifying a

radar contact as the SS SILVER DOVE.

Rescue of the 33 crew members in the lifeboats still secured to the vessel at the end of the 900-foot line was accomplished without incident, using the CGC NORTHWIND's 26' motorboat, and was completed at 0532. Communications were established between the salvage detail on the SS SILVER DOVE and the CGC NORTHWIND utilizing the portable radio recovered from the lifeboats. Rescue of the persons on the SS SILVER DOVE awaited daylight. The vessel was rolling between 15 and 37 degrees to port.

At about 0600, the chief engineer entered the upper tween deck area between #3 and #4 holds. He noted sugar and water along the port side up to the overhead at the hull. He also looked down the ladder leading to the port diffuser room and saw the water level was up to the second step.

At 0705, the remaining persons on the SS SILVER DOVE were removed from the stern of the SS SILVER DOVE by the CGC NORTHWIND's boat. Swells were about 8 foot with 15- to 20-knot winds.

The SS ARIANTA arrived on scene at 1026, received medical advice for a sick passenger from the medical officer aboard the CGC NORTHWIND, was released from rendering further assistance to the SS SILVER DOVE, and proceeded to Johnston Island.

The CGC NORTHWIND's medical officer examined all crew members of the SS SILVER DOVE and found no injuries; some crew members, however, suffered sunburn.

Close examination of the SS SILVER DOVE from the CGC NORTHWIND did not disclose any signs of hull failure. All hatch covers appeared secure. The period of roll measured as 11 seconds in the morning increased as the day progressed to about 15 seconds. The amount of what was believed to be sugar and oil which appeared to be coming from the midships area also increased during the day. Because of the port list, which reached 30 degrees by afternoon, it was considered imprudent to place a salvage crew aboard. Conversations with the master indicated there were no suitable pumps available and that any dewatering would have to take place from deep within the vessel. Towing of the SS SILVER DOVE was considered impractical because of the SS SILVER DOVE's apparent worsening stability. The SS SILVER DOVE was noted to be increasingly sluggish in the return from port rolls.

Ashore in Honolulu, the owner's representative was arranging for salvage services.

That evening, the CGC NORTHWIND kept track of the drifting hulk by

running on parallel courses close to the vessel. At 0255, on 2 April 1973, the radar pip of the SS SILVER DOVE disappeared from the radar scope while at a range of two miles. The vessel sank in 2500 fathoms of water at 14° 04' North, 171° 25' West. Two lights were observed in the vicinity and at daylight the lights were identified as the two inflatable rafts from the SS SILVER DOVE.

The CGC NORTHWIND, while standing by with 40 survivors, recovered both life rafts and sunk both lifeboats by gunfire; and then proceeded to Honolulu, Hawaii, at which port the survivors disembarked.

6. Cargo Description: The sugar cargo carried in bulk on the SS SILVER DOVE was Philippine raw centrifugal sugar. It is the product of centrifugal spinning of "massecuite," the first and second boiling in the sugar factory. The massecuite is a mixture of a molasses-like liquid and sugar crystals. The spinning throws off the molasses, leaving 97% to 98% crystals remaining. The crystals and small amount of liquid remaining are a two-phase system which settles in equilibrium. Basically, the solid sugar crystals are surrounded by a coating of liquid which is saturated with dissolved sugar and is like molasses.

As water is added to the bulk sugar, either in liquid form or through humidity, more of the solid crystals go into solution until a new balance or equilibrium is reached. The converse is also true.

Water introduced at the top of a cargo of bulk sugar will pass to the bottom. As the water passes over the crystals, it washes off the liquid coating on the crystals, which will dissolve in the water as it flows to the bottom of the cargo. If no further water were introduced and the heterogeneous mixture were left indefinitely, equilibrium between the water and the cargo would be reached throughout the hold. No. 3 lower cargo hold, which contained approximately 1640 L/T of sugar, could reach a fluid state by the addition of between 400 and 450 tons of water. A lesser amount of water could create a fluid state in the lower portion of the cargo which was initially exposed to the water.

"Stowage of Bulk Cargoes," a manual printed and distributed by the National Cargo Bureau and endorsed by the Coast Guard (46 CFR 97.12-5), implements the Inter-Governmental Maritime Consultive Organization (IMCO) "Code of Safe Practice for Bulk Cargoes." Appendix A to this manual, pertaining to "dry" (ores and similar bulk) cargoes, lists sugar. General precautions relative to stowage of cargoes are noted in section 2. Sections 3 and 4 of the manual pertain to cargoes listed in Appendix A. Sections 5.2 and 5.5, which caution the carrier in regard to excessive moisture and viscous fluid behavior of cargo, apply only to "wet" (ore concentrates) cargoes listed in Appendix B, which does not include sugar.

7. Previous Inspections: The SS SILVER DOVE underwent a Coast Guard drydock examination and a Special Periodical Survey No. 5 for the American Bureau of Shipping in New Orleans in May 1972. Part of this special survey entailed ultrasonic gauging of the hull. The ultrasonic testing was done by Mobile Lab, Division of Smith International, Harvey, Louisiana, using a Bronson Sonoray Model 301 instrument. There was no supervision of the technicians by ABS and no instructions were given them except as to which plates were to be gauged. The only condition was that the gauging was not to be taken opposite a frame or deck. The hull plating was gauged in the "wind and water" area of "G" and "H" strakes and two belts, one in way of frame 60 and another belt in way of frame 126. Apparently, gauging locations on specified plates were chosen at random by the technician, when taken from a crane bucket, based on convenience, and not on whether the area was wasted or sound. One gauge reading was taken on each plate examined; and if there was reason for the technician to doubt the reading obtained, or if low readings were obtained, a second reading would be taken and an average of the readings taken was recorded. A copy of the ultrasonic inspection results was furnished to the Coast Guard Inspector, who reviewed the readings and discussed them briefly with the American Bureau of Shipping Surveyor. The readings were found to be within the 25% tolerance of deterioration permitted by Navigation and Inspection Circular 7-68.

Plate SG-12, which extended between frame 94-1/2 and frame 105-1/2, was located 15 feet, 3 inches, to 23 feet, 3 inches, above the vessel's keel. The upper seam of the plate was located 1 foot, 6 inches, above the third deck. Plate SG-12 was gauged and found to have a reading of .670 inches. The original thickness of this plate specified in the shell expansion plans was 0.65 inches (26.1 pound plate).

The Coast Guard inspection of the hull structure on 25 May 1972 consisted of a visual inspection of accessible portions of the interior of the vessel. The visual inspection of the outside of the hull from the drydock floor did not reveal any unusual wastage or plate deformities warranting removal of the sheathing, additional testing or closer examination of any area. The Coast Guard inspector was satisfied that the hull was in seaworthy condition, based on his visual observation and review of the ultrasonic readings. Repair to several sea valves and overboard shell connections was accomplished during the drydocking period.

No hull insulation was removed in way of the #3 hold refrigerated spaces or diffuser rooms; thus the condition of the interior hull plating and frames in #3 lower tween decks was not determined.

ABS Special Periodical Survey No. 5, which the vessel was undergoing, required the survey to be at least as comprehensive as Special Periodical Survey No. 2, with special attention being given to the condition and thickness of material liable to corrosion. The thicknesses of the shell, deck and other members which had not been previously ascertained are to be determined, having regard to the degree of wastage previously indicated by a review of the records of the vessel.

ABS Special Periodical Survey No. 3, completed in August 1961, required in part that spaces insulated in connection with refrigeration, the limbers and hatches were to be lifted and enough lining was to be removed from all spaces to enable the surveyors to satisfy themselves as to the general condition of the plating and framing in way of the insulation.

8. Shelter Deck Design: The SS SILVER DOVE was originally built as a "shelter deck" designed vessel for purposes of documentation and loadline regulations. The vessel was designed with tonnage openings between the cargo holds and midship machinery spaces on each side of the upper tween deck level. The 5 watertight bulkheads between the several cargo holds and machinery spaces were effectively watertight up to the second deck level. The tonnage openings between cargo holds were approximately 7'6" high and 9' wide; and the tonnage openings between #3 and #4 cargo holds and the machinery spaces were 7'6" high and 3'6" wide and were all flush with the second deck level. The tonnage openings were fitted with battens to provide nonwatertight closure.

A tonnage hatch was installed on the weather deck between frames 178 and 180. The hatch opening measured 4'5-1/2"x24' and was made weathertight by hatch boards and batten-type closures.

The cargo hatch closures in the second deck consisted of hatch beams placed athwartships on which hatch boards were fitted. The hatches were constructed with the provision that they could be made effectively watertight by means of tarpaulins, battens and wedges which could be secured inside a recess in the hatch perimeter. During the voyage when the casualty occurred, the hatches were not covered and only the hatch beams were in place.

Provisions for drainage of the upper tween deck consisted of 4" pipe drains in the after corner of #3 and forward corner of #4 cargo holds. The drains led overboard approximately 12" below the second deck level and were originally fitted with a scupper plug which was restrained in the pipe by a yoke and set screw for effecting a seal on the upper tween deck level.

In addition, 2" deck drains were provided in the after corner of #2 and #3 holds and the forward corner of #4 hold. These drains and a 2" drain for the cargo side ports led into a common 2" drain line which discharged through a clapper-type scupper valve in the vessel's side.

The Certificate of Admeasurement issued by the Coast Guard on 20 March 1967 in the port of New York assigned a gross and net tonnage and measurement under the provisions of 46 CFR 69.15 for single tonnage assignment with the tonnage mark on the same level as the assigned loadline. The current loadline certificate measures the effective freeboard of the vessel from the second deck level.

CONCLUSIONS

1. The SS SILVER DOVE capsized and sank after the vessel developed hull failures in way of plate SG-12 and experienced a 22-degree port list due to a sudden shift of flooding water and dissolved sugar cargo from the starboard to port side of #3 hold. Additional flooding water entered the hull through submerged hull fittings in or above the upper tween (freeboard) deck, resulting in a total loss of righting moment.

2. The entry of water into the vessel after the initial 22-degree list to port probably occurred through one or more leaking 2" scupper check valves located in overboard drains for #2, #3 and/or #4 cargo holds. The drains serving both the upper tween deck and the cargo port drain wells were cemented over prior to loading the bulk cargo; however, it is concluded that the failure of one or more of the scupper valves would have subjected the concrete drain seals to sufficient hydrostatic pressure when the vessel listed 22 degrees to port to dislodge the seals, thus permitting water to enter the vessel at a restricted rate.

3. Some leakage of flooding water into the hull could also have occurred in way of the upper tween deck cargo side port located in #2, #3, #4 and #5 holds and the storing ports located amidships. The storing port, which opened inboard, was most susceptible to leakage when submerged. The cargo and storing ports were required to meet only a weathertight closure criterion since they were located above the freeboard deck.

4. The flooding water entering the upper tween deck was able to progress throughout the length of the vessel between the forepeak and afterpeak bulkheads by way of the shelter deck tonnage openings and, when the flooding water in the upper tween deck reached sufficient height, down flooding occurred through the open cargo hatches in the freeboard deck.

5. The lack of any effective means to secure the drains or the cargo side ports, which were blocked by the sugar cargo in the upper tween deck, precluded the crew from taking any action to reduce the additional flooding.

6. The proximate cause of the 22-degree port list was the transverse shift of cargo in #3 cargo hold, resulting from events during the voyage which occurred in the following chronological order:

   a. A hull failure characterized as a crack approximately 8" long in the starboard hull plate SG-12 at frame 100 in the #3 refrigerated

diffuser room, which was discovered at sea on 17 March 1973, permitted water to flow into the lower tween deck, then through the wasted third deck into the bulk sugar cargo in #3 lower hold. The crew was unable to adequately stop the flow of water into the vessel through the crack because of its location and interferences (frame 100 and the adjacent built-up deck insulation) and the vessel diverted to Guam for temporary repairs.

b. The temporary repairs which were accomplished between frames 99 and 101 at Guam, although they stopped the leakage at frame 100, did not include any provisions for strengthening sections of the plating adjacent to the patched area.

c. A subsequent hull failure, discovered at sea on 30 March 1973 in the same horizontal plane as the previous failure in the adjacent frame space between frame 101 and the after bulkhead (frame 102), permitted additional water to enter the vessel and flow into the #3 lower hold.

d. The vessel's personnel were unable to control or effectively check the sizable flow of water into the hull through the second hull failure. The vessel's officers did not continue efforts during the early morning hours of 31 March to reduce the inflow of water in way of the new leak or check on the degree of flooding water entering the vessel.

e. The vessel's personnel were unable to pump out any significant quantity of the water entering the #3 hold because of the nature of the cargo, and the manner in which the bilge wells were covered with burlap. The flooding water caused a gradual transition of some of the bulk sugar cargo in the bottom of #3 lower hold from a stable crystalline form to a liquid molasses form. This fluid cargo was initially confined to the starboard side where the water was entering the hull, and was retained there due to the resulting starboard list.

f. The transfer and addition of liquids to the port side over a period of several days, ending at 0630, 31 March 1973, to compensate for an increasing starboard list, created a port moment of 12,754 foot tons. This port moment consisted of a 224-ton differential in #3 double bottoms with an effective moment of 4,424 foot tons, a 158-ton differential in #4 double bottoms with an effective moment of 2,570 foot tons and a 380-ton differential in the #4A deep tanks with an effective moment of 5,760 foot tons.

g. The last transfer of oil contaminated with water from #3 starboard double bottom to #5 port deep tank on the morning of 31 March reduced the starboard list from 3 or 4 degrees to 2 degrees. Between 0630 and 0937, the gradual flow of liquified sugar from starboard to port in the lower #3 hold resulted in a shift of approximately 180 tons from the starboard to the port side, most of which took place in the last 12 minutes. This shift of off-center weight created a port heeling moment of 8,500 foot tons which, when added to the port heeling moment from the unequal tank loading, caused a 22-degree port list. The cross curves of stability for the vessel in a fully loaded condition of 18,500 tons displacement indicate that a moment of 21,200 foot tons would produce a list of 22 degrees, assuming a KG of 27.2 feet.

7. A major contributing factor was the failure of the vessel's officers or the inspection and repair personnel to accurately assess the nature of the failure and the condition of the hull in the area adjacent to the leak when the vessel was at Guam for temporary repairs on 21 March 1973. The failure of the vessel's officers and inspection personnel at Guam to remove or require removal of additional insulation and sheathing to permit examination of the hull in the adjacent frame spaces before establishing the extent of the temporary repair precluded an adequate evaluation of the degree of deterioration in adjacent frame spaces. That the inspection and repair personnel did not want to disturb the plating is understandable; however, every attempt by nondestructive means should have been used to determine the adequacy of the hull plating below the level of the insulated deck and either side of frames 99 and 101. In hindsight, had the sheathing between frame 101 and the aft bulkhead been removed, the additional deterioration of the hull and vent line would have been observed and perhaps influenced the extent of the temporary repair.

8. Another major contributing cause was the failure of the vessel's officers to fully recognize the adverse effects on stability created by the unsymmetrical liquid loading of the vessel's tanks to counteract the starboard list and by the free surface effect of liquified sugar cargo. This was evidenced by the failure of the officers to continue their efforts to reduce the inflow of water throughout the night of 30-31 March 1973.

9. The general precautions contained in the manual "Stowage of Bulk Cargoes," referred to in 46 CFR 97.12-5, are inadequate to alert personnel to the specific hazards of a shift of "dry" bulk cargoes listed in Appendix A when water is added.

10. The exact cause of the hull failures is unknown. Testimony provides conflicting descriptions of the faults. Heavy deterioration was observed by many of the persons who were involved with the repairs. The probable cause was localized corrosion in the trough formed by the deck plate, the built-up deck insulation and the shell plate where moisture from condensation, water, and brine spills could collect. This corrosion resulted in reduction in plate thickness and severe pitting near the deck. The plate thickness near the deck was probably reduced to a point where the combination of plate stress plus stress concentration factors associated with pits and possibly through holes resulted in a number of plate penetrations connected by a fracture line. Since the exposure to the corrosive environment would be essentially identical in the three after frame spaces, it is conceivable that the plate failure could occur in several places over a short time span. The evidence indicates that an indentation existed in way of the original failure in plate SG-12. It is concluded that such an indented condition in way of deteriorated plate would have influenced the location and the extent of the original hull failure.

11. The crew made every attempt to locate the source of leakage of water into #3 lower hold after the westward voyage to Saigon, and concluded that the main source of water came from the deteriorated vent trunks on the main deck, which they blanked off. The master and other officers were still not satisfied and removed sheathing and insulation, drilled test borings into the #3 lower tween deck refrigerated box insulation and made external examination of the hull plating to find other possible sources of leakage. It is concluded that the hull failure in way of the starboard diffuser room may have existed on the westbound voyage in addition to the leaking vent trunks, and that the amount of leakage was such that it could drain into the lower hold without detection behind the refrigerated box insulation. Since the examination of #3 lower hold was not made until the vessel was partially off-loaded when the affected portion of the hull would have been above the existing waterline, detection of a small hull leak at Saigon or during the voyage to Batangas while the vessel was proceeding without cargo would have been difficult.

12. The SS SILVER DOVE was built to essentially a one-compartment standard of subdivision below the freeboard deck, which exceeds the current ABS classification rules for construction of cargo vessels. The flooding below the freeboard deck in #3 hold was confined to the limited section of the vessel only because of these additional subdivision bulkheads. The extension of these watertight bulkheads above the freeboard deck to the weather deck would have prevented progressive longitudinal flooding. The

down flooding in #3 hatch would still have occurred because of the open cargo hatch in the freeboard deck. The freeboard deck drains were ineffective once the vessel listed to an angle where the freeboard deck edge was below the existing waterline and there were no alternate provisions for the rapid removal of the entrapped water.

13. Prior to foundering, little significant water entered the vessel through the weather deck openings into the deckhouse and hull. All openings were secure except for one open porthole on the main deck which could not be closed. The surface slick noted after abandonment was probably due to dissolved sugar cargo which lay against the cargo side ports and seeped out of the underwater openings as the vessel rolled in the seaway.

14. The abandonment of the vessel was timely and efficient. Some raising and lowering of the starboard lifeboat was necessary to free the boat fall block from the davit hook as the vessel rolled between 12 and 27 degrees. The crew was able to successfully launch the starboard boat by timing the descent of the boat with the favorable rolls and the use of makeshift skids.

15. The use of portable radios to maintain contact between the salvage detail and the lifeboats was very effective.

16. The use of the 900' line trailing from the SS SILVER DOVE to which both boats were tied to keep together in the vicinity of the stricken vessel until rescue units arrived materially contributed to the quick recovery of the survivors.

17. The continuous activation of the radio auto-alarm after abandonment, although it could assist rescue units to home on the signal, appears to have unnecessarily disrupted communications on the distress frequency 500 kilohertz.

18. The accuracy of the results of the ultrasonic testing conducted during the last drydocking in New Orleans on which both the Coast Guard inspector and the ABS surveyor relied is subject to serious doubt. The ultrasonic gaugings show some plating thicknesses, including plate SG-12, in excess of the scantlings to which the vessel was constructed. The testimony indicates that the exterior of the plating, as well as the exposed portions of the interior plating in #3 lower tween decks, showed evidence of scaling which ordinarily is associated with a reduction of plate thickness. That some of the plates gauged may have been renewed is probable; however, the overall gaugings did not determine either

the minimum or the average thickness of the shell plating or the reduced thickness of plate SG-12. No attempt was made to insure that readings were taken in way of areas subject to unusual internal corrosion.

19. The use of ultrasonic gauging without either outlining the places to be gauged, conducting test borings, inspecting both sides of the plate for localized corrosion, or otherwise verifying readings provides an uncertain survey of hull condition. The procedures for the ultrasonic testing outlined in Navigation and Inspection Circular 7-68 are adequate and, if followed during the drydock inspection, would have resulted in readings that were more truly representative of the vessel's actual hull condition.

20. The inspection procedures used during the last drydocking period to evaluate the hull condition of a 26-year-old vessel were according to accepted marine practice but were inadequate to provide a reasonable assessment of the vessel's actual hull condition, especially in way of the refrigerated spaces, without removal of sufficient insulation to expose sections of the hull which were subject to accelerated corrosion.

21. The installed bilge drainage system in #3 hold as designed was sufficient to remove the water which entered the lower hold if it had reached the bilge well. The vessel's personnel, although they were unable to pump the #3 starboard bilge well through the fixed bilge system because of a blocked suction line, were able by occasional pumping to effectively remove the water and cargo mixture which reached #3 starboard bilge well with a jury rigged hose connected to the bilge sounding pipe.

22. A portion of the flooding water entering the vessel on the lower tween deck level from the second leak could have been removed through the sump drain in the starboard lobby if the drain had not been blocked. The air pump used for dewatering was not fully effective because of the limited supply of compressed air.

23. The vessel's personnel were unable to determine the extent of flooding in #3 hold since the recorded bilge well soundings did not change significantly. The fact that only a small amount of flooding water/cargo mixture found its way into the starboard bilge well or the test nipples after the second leak had developed cannot be explained, especially in view of the circumstances which permitted a significant volume of water to shoot out of the test connection after the first leak was discovered.

The fact that wet sugar flowed from the test connection and that a syrup-like substance was pumped from #3 starboard bilge well indicates that the bulk cargo sugar in the bottom of the hold at that location had a thick viscous consistency. The flow of the thick water/cargo mixture to the bilge well most probably was restricted by the burlap covering over the perforated bilge well cover or high hat and concrete seal.

24. Since the vessel's personnel did not periodically check on the flooding condition in #3 lower tween deck throughout the early morning hours of 31 March, they were unaware of any changes in the degree of flooding or other conditions which occurred. A large portion of the volume of water necessary for the transverse weight shift and resulting 22-degree list most probably entered the vessel between midnight and the time of the sudden list.

25. There does not appear to be any evidence of any significant shifting of the unaffected sugar cargo which contributed to this casualty.

26. The physical ability of the crew of the SS SILVER DOVE to respond in this emergency after abandonment while in the lifeboats was adversely affected by seasickness. The crew's ineffectiveness when ordered to row to the vessel and to retrieve the portable radios dropped from the aircraft was in large part due to the effects of motion sickness in the existing sea condition.

27. The conduct of two of the crew in #1 lifeboat when ordered to row back to the vessel to pick up the two officers amounts to misconduct.

28. There were no injuries to the crew or loss of life as a result of this casualty. Some crew members did, however, suffer minor effects from exposure to the sun while they were adrift in the lifeboats.

29. Although there is no evidence of willful misconduct or actionable negligence on the part of shipboard, inspection and repair personnel involved in the temporary repair at Guam which contributed to this casualty, the evidence does indicate a lack of diligence on the part of involved personnel in determining the extent of hull deterioration in the areas adjacent to the temporary repair.

30. The immediate response by Coast Guard and Air Force aircraft led to rapid location of the stricken vessel. The continuing air coverage was effective in reducing search time by surface units and provided an invaluable morale factor to the crew members.

31. The rescue of the crew members of the SS SILVER DOVE by the USCGC NORTHWIND from the lifeboats during the early morning hours of 1 April 1973 and subsequent removal of 7 persons from the SS SILVER DOVE without mishap in the sea condition and the vessel's attitude which existed is worthy of special recognition.

RECOMMENDATIONS

The recommendations of the Board are:

1. That mandatory requirements for periodic inspection of selected areas of vessels which are not normally accessible to visual inspection, and periodic inspection of specific shipboard operating equipment should be considered. Documentation of findings in such inspections should be centralized for ready access of inspection personnel. The information obtained could also be used to identify trends in the structural adequacy and reliability of equipment approved for shipboard use.

2. That hull plating and structural areas in way of cargo or vessel's stores refrigerated spaces, and tanks or compartments which are covered by insulation be required to be exposed for detailed examination of the members at periodic intervals. Access for inspection should be specifically required in those areas where brine spills or condensation drainage can collect or where lack of ventilation can enhance deterioration.

3. That cargo and miscellaneous vessels be required to meet damaged stability criteria since the present classification rules for construction and assignment of load line appear to be inadequate in providing inherent protection from the adverse effects of extensive accidental flooding.

4. That weathertight standard be required on all closures in the freeboard deck of shelter-type vessels to preclude down flooding within the hull structure. If these closures by design or location within cargo spaces will be inaccessible during the voyage, a requirement for their closure prior to loading or departure from the port should be considered. The load line regulations should be amended to include a requirement for the closure of hatches in the freeboard deck when vessels are underway.

5. That standards be developed requiring a means of discharging water which may be introduced and confined above the freeboard deck of shelter-type vessels in a listed condition.

6. That a recommendation be made to IMCO to modify the existing "Code of Safe Practice for Bulk Cargoes" to recognize the hazards associated with "dry" bulk cargoes listed in Appendix A when water is added.

7. That consideration be given to including a motion sickness medication in lifeboats and liferaft survival equipment in view of the

debilitating effects of motion sickness on the personnel and their consequent inability to function effectively while in lifeboats.

8. That disciplinary action under R.S. 4450 as amended be taken looking towards suspension or revocation of the documents of crew members who were logged for their misconduct while in #1 lifeboat.

A. S. ZABINSKI, CAPT, USCG
Chairman

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Member and Recorder

C. B. GLASS, CDR, USCG
Member