MEMORANDUM

date November 17, 1992

to Mayor and City Council

from John F. Shirey, Assistant City Manager

subject <u>Queen Mary Hull Condition Survey</u>

Attached is the text portion of the recently completed marine engineering survey of the Queen Mary performed by International Diving Services. By the end of the week we will be transmitting to you a complete report, including the sections for each of the inspection locations with photographs, along with laboratory reports.

JFS:GDV:ch
Attachment
cc: John R. Calhoun, City Attorney
Gary L. Burroughs, City Auditor
Shelba F. Powell, City Clerk

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CITY OF LONG BEACH

RMS QUEEN MARY

CATHODIC PROTECTION

AND SHELL CONDITION SURVEY

JOB NO. 2369

NOVEMBER 4, 1992

Prepared by:

INTERNATIONAL DIVING SERVICES

And

PK MARINE

Submitted: November 13, 1992

741 ARCTURUS ROAD • OXNARD, CALIFORNIA 93033 • (805) 488-6428 • FAX (805) 986-5309

SECTION I

INTRODUCTION AND INSPECTION SUMMARY

1.1 GENERAL

The City of Long Beach, California is investigating the feasibility of taking over responsibility for maintenance and operation of the RMS Queen Mary from the Port of Long Beach. International Diving Services (IDS) and its sub-consultant, PK Marine (PKM), were retained to perform an underwater survey of the hull of the Queen Mary, as part of that feasibility investigation. The following is a report on the methods used to perform the survey, the data collected, an analysis of the findings, and recommendations for future action.

Given the extremely short time frame available to perform this survey, and the magnitude of this ship, random sampling methods were used to obtain data. We feel that this method has given us an accurate representation of the condition of the underwater hull. We cannot guarantee however that there my not be some isolated areas of greater wastage. None of the survey team has been in any way associated with the preparers of previous reports, nor with any company or individual having an interest in the future of the Queen Mary. This report is prepared without prejudice or bias.

1 2 PROJECT HISTORY

On October 22, 1992, the City of Long Beach issued a request for proposals from "Qualified Marine Architects/Surveyors" to immediately undertake an examination of the condition of the hull of the Queen Mary. The following "Proposed" Scope of Work was included with the RFP.

The City is seeking a qualified marine Engineer to inspect and evaluate the structural integrity of the hull of the Queen Mary. The City has received a comprehensive vessel analysis performed by Rados International Corporation which has included an evaluation of all systems within the ship to determine repairs and maintenance that would be required to bring the floating structure up to industry standards.

It is the City's desire to have the entire hull beneath the water line cleaned; ultrasonically tested to determine plate thickness; x-ray critical welds in the propeller box areas, and various sea chest areas; visually inspect rivet heads; produce an underwater video and prepare an evaluation report on the condition of the hull for the City. This entire process would be accomplished in water, as the ship currently sits. Time is of the essence and will be a critical factor during this evaluation process.

Hull characteristics for the Queen Mary since its conversion are as follows:

Overall Length	1019.6 feet
Draft	34.5 feet
Exterior Underwater Hull Plating	150,000 feet

The team of International Diving Services and PK Marine presented their proposal before the City's selection board on Thursday, October 29, 1992. We were notified of our selection later that same day. A contract was signed on Tuesday, November 3, 1992 and the inspection team was on site Wednesday, November 4, 1992. Data collection was completed by Monday evening, November 9, 1992, and selected areas were rephotographed on Tuesday, November 10, 1992. An informal report of findings and recommendations was presented to the City on Monday, November 9, 1992. The following is our formal report, and, along with accompanying videos, constitutes the final deliverable for this project.

1.3 SCOPE OF WORK

The following scope of work was performed per the contract:

1.3.1 **Cathodic Protection Survey** - IDS conducted a cathodic protection voltage potential survey prior to cleaning the hull. This underwater survey was performed by divers utilizing silver/silver chloride half cell and documented by the IDS Diving Supervisor. Cathodic protection potential measurements were taken on the underwater parts of the ship every 20' along 24 transverse lines spaced longitudinally along the hull approximately every 40'. They resulted in readings at approximately 400 charted coordinates on the hull. These coordinates are presented on a shell expansion drawing in an isopleth format.

1.3.2 **Inspection Locations** - IDS spot cleaned sixteen (16) locations on the hull. Each location measured approximately 10' x 10' and was cleaned to bare metal with IDS hydroblasting systems. The locations are identified on the final shell expansion drawing in reference to frame numbers and number of feet from the centerline of the ship. The following locations were designated as inspection locations.

a. Port Side - one near bow, one near midships and one near stern.

b. Starboard Side - one near bow, one near midships and one near stern.

c. Bow - one location on the bow.

d. Stern - one location on the stern.

e. Flatbottom - one near the bow, one near midships and one near stern.

f. Stern Tube - one location surrounding a stern tube.

g. Sea Chests - three blanked sea chest and surrounding shell plating.

h. Propeller Viewing Box - one location of the propeller viewing box.

1.3.3 **Pit Gauging** - IDS performed random sample pit gauging measurements of significant pitting found at all inspection locations. This included pitting of welds and plating.

1.3.4 **Ultrasonic Thickness Gauging** - IDS performed ultrasonic thickness gauging of the shell plating at 10 to 15 randomly selected locations at each inspection location.

1.3.5 **Magnetic Particle Inspection (MPI)** - IDS visually inspected the external welds of the viewing box and the three sea chest blanking plate-to-shell plating welds. A total of 20' linear feet of weld on the viewing box will be inspected with MPI. IDS also performed MPI of certain welds on the sea chest blanking plate-to-shell plating.

1.3.6 **Rivet Inspection** - IDS used calipers to measure the diameter of rivet heads on 10 to 15 rivets at each inspection location. The removal of the rivets, originally scheduled, was not performed but was substituted with a radiographic inspection.

1.3.7 **Documentation** - IDS video taped all inspection locations after they were cleaned. Any anomalies were also video taped. IDS photographed the inspection locations and pertinent conditions found at the inspection locations. All non-destructive testing data was documented on IDS NDT forms by the Diving Supervisor or IDS Project Manager.

1.3.8 **Inspection Report and Recommendations** - The IDS inspection report was to include:

a. A summary of the cleaning and inspection.

b. A section for each inspection location which is devoted to the information obtained at that inspection location.

c. A photographic log.

d. A video log.

e. A shell expansion drawing with isopleth of cathodic protection potentials.

f. Marine engineering summary and recommendations.

1.4 OVERVIEW

1.4.1 Findings

a. **Cathodic Protection System** - The cathodic protection system is properly adjusted and providing good protection over most of the underwater hull. An area of shadowing does exist along centerline in the aft quarter of the ship. Recommendations for treatment of this area are included in this report.

b. **Shell Thickness** - Based on our random sampling, the shell plating thickness varies between 0.50" and 1.29" throughout the underwater hull. Pits average about 1/16" deep and, for the most part, have not changed since the ship was last drydocked.

c. **Rivet Condition** - External rivet heads show the same evidence of old corrosion as the shell plate. Rivet shanks appear to be intact and there is no evidence of rivet leaks. Some internal rivet heads are badly corroded, but are not leaking.

1.4.2 Response to Past Reports of Catastrophic Damage

The severe corrosion inside the ship, as discussed in previous reports, was randomly inspected. While the wastage is severe, no structural failure was observed and the ship is not in imminent danger of a catastrophic failure. Preventive measures necessary to arrest this deterioration, all of which can be performed with the ship on location in the water, are discussed in this report.

1.4.3 Summary of Recommendations

We recommend that, if the City of Long Beach wishes to retain the Queen Mary, that they do the following to maintain the status quo for the next three to five years. All work contained in these recommendations can be accomplished with the ship in the water, at her present location.

a. Maintain the cathodic protection system as currently operating. Have divers install new sacrificial anodes in the shadowed areas, and where former anodes have been consumed.

b. Leave the existing layer of marine growth, which is providing protection to the hull surface, intact.

c. Maintain the new coating system, currently being applied, at the splash zone.

1.4.4 Clean, sandblast, repair, and paint all interior spaces where damaging corrosion has taken place. Install a functioning bilge pumping system, and restore selected watertight bulkheads.

SECTION 2

CATHODIC PROTECTION SYSTEM SURVEY

2.1 METHODS AND EQUIPMENT

2.1.1 **Purpose of Survey** - The primary factor in the preservation of the underwater parts of the RMS Queen Mary is its cathodic protection system. This system substantially limits or prevents the deterioration of the ship's underwater steel parts as a result of the natural galvanic action created by the ship's steel hull and the sea water it floats in.

The cathodic protection system currently in use on the RMS Queen Mary is an "impressed current" system. Basically, this system consists of electrically charged anodes which are suspended in the water alongside the ship. These anodes create an electrical field which results in protection to the underwater steel parts of the ship.

There is no record that the output, or "voltage potential" has ever been properly mapped. Past voltage potential measurements have been conducted along one side of the ship but a complete mapping was necessary to determine if there were are any unprotected zones on the ship's flat bottom. Once mapped, unprotected or shadowed areas of the hull can be identified and additional protection applied. IDS performed such a mapping as part of this inspection.

2.1.2 **Survey Procedures** - The survey was conducted with a diver held silver/silver chloride reference cell. The cell is connected to a volt meter on the surface through an electrical cable married into the diver's umbilical. A ground wire is attached to the hull of the ship and also connected to the volt meter. Prior to each dive, the reference cell is calibrated to zero and -1.500 mV.

The survey was mapped through the use of a grid system. The grid system was established for the underwater portion of the hull using ship's frame numbers and hogging lines. Longitudinal stations were established at approximately 40 foot intervals for the hogging lines. These stations were sequentially numbered from 1 through 24, starting at the bow, on both sides of the ship. The ship's frame number, corresponding to each station was identified. A hogging line was run transversely under the ship at each station. These lines were marked with tags at five foot intervals from the keel up to the waterline both port and starboard. All readings taken underwater were thus identified by station (or frame) number and by distance around the girth of the ship, port or starboard, measured from the keel.

Cathodic protection voltage potential readings were taken at 20 foot intervals at each hogging line from waterline on the port side to waterline on the starboard side.

2.1.3 **Findings** - The voltage potential measurements ranged from as high as -1.055 mV to as low as -.630 mV. A voltage of potential reading of -.800 mV and lower is consider to be inadequate.

The majority of the measurements were above the -.800 mV mark and the impressed current cathodic protection system currently in use appears to be functioning well and providing adequate protection to the majority of the shell plating.

One zone of low and inadequate coverage was found on the ship's flat bottom, however, between frame #39 and #117 the lack of protection is quite serious and should be corrected as soon as possible. (See the following drawing "Isopleth of Cathodic Voltage Potentials"

2.1.4 **Isopleth Drawing**

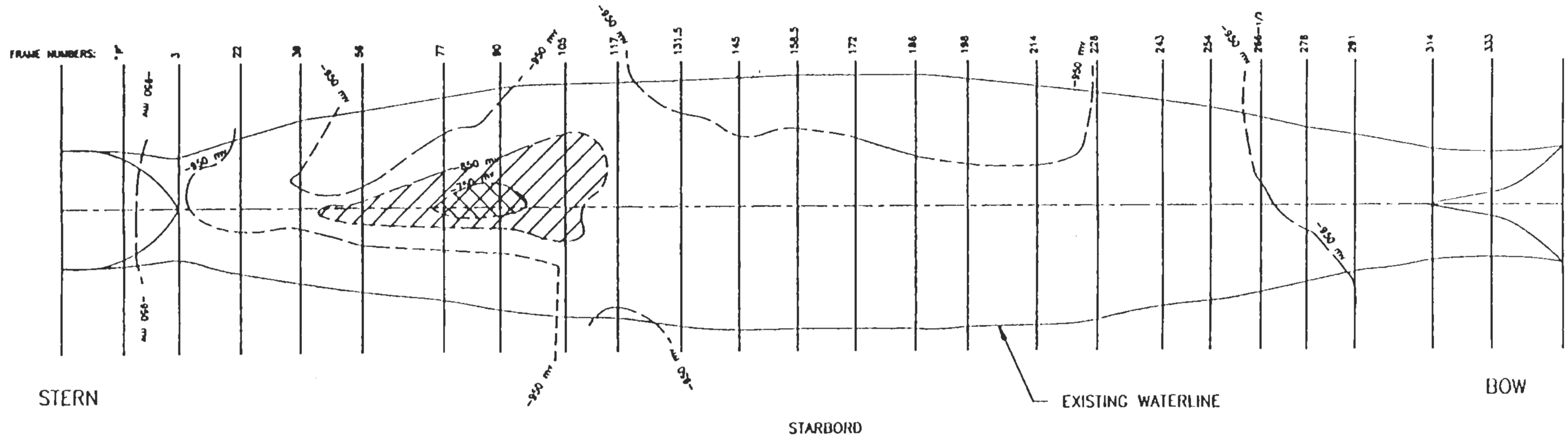
= AREA OF READINGS −850 mv. to −750 mv.

= AREA OF READINGS −750 mv. to −630 mv.

ISOPLETH LEGEND:

−950 mv. = −950 mv to −1044 mv
−850 mv. = −850 mv to −950 mv
−750 mv. = −630 mv to −850 mv

NOTE: THERE IS A VIEWING BOX AT FRAME #22 ON THE PORT SIDE.



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QUEEN MARY SHELL EXPANSION
WITH
CATHODIC PROTECTION ISOPLETH
FOR
CITY OF LONG BEACH
SCALE 1" = 80'   NOVEMBER 1992

SECTION 3

EXTERNAL INSPECTION

3.1 INSPECTION LOCATION SUMMARY

External inspection of the ship's shell plating and underwater parts was conducted at 16 separate "inspection locations". Each location consisted of a square approximately 10' x 10' in size. These location were:

3.1.1 Inspection Location #1: Stern, Frame Q, at centerline.

3.1.2 Inspection Location #2: Stern tube, inboard, port side.

3.1.3 Inspection Location #3: Viewing Box, port side.

3.1.4 Inspection Location #4: Port side, Frame 86, 30' port of centerline.

3.1.5 Inspection Location #5: Centerline, Frame 86.

3.1.6 Inspection Location #6: Starboard side, Frame 86, starboard 30' of centerline.

3.1.7 Inspection Location #7: Sea chest, Frame 86, starboard 35' of centerline.

3.1.8 Inspection Location #8: Sea chest, Frame 107, port 30' of centerline.

3.1.9 Inspection Location #9: Sea chest, Frame 111, starboard 30' of centerline.

3.1.10 Inspection Location #10: Sea chest and port side, Frame 186, port 55' of centerline.

3.1.11 Inspection Location #11: Centerline, Frame 186.

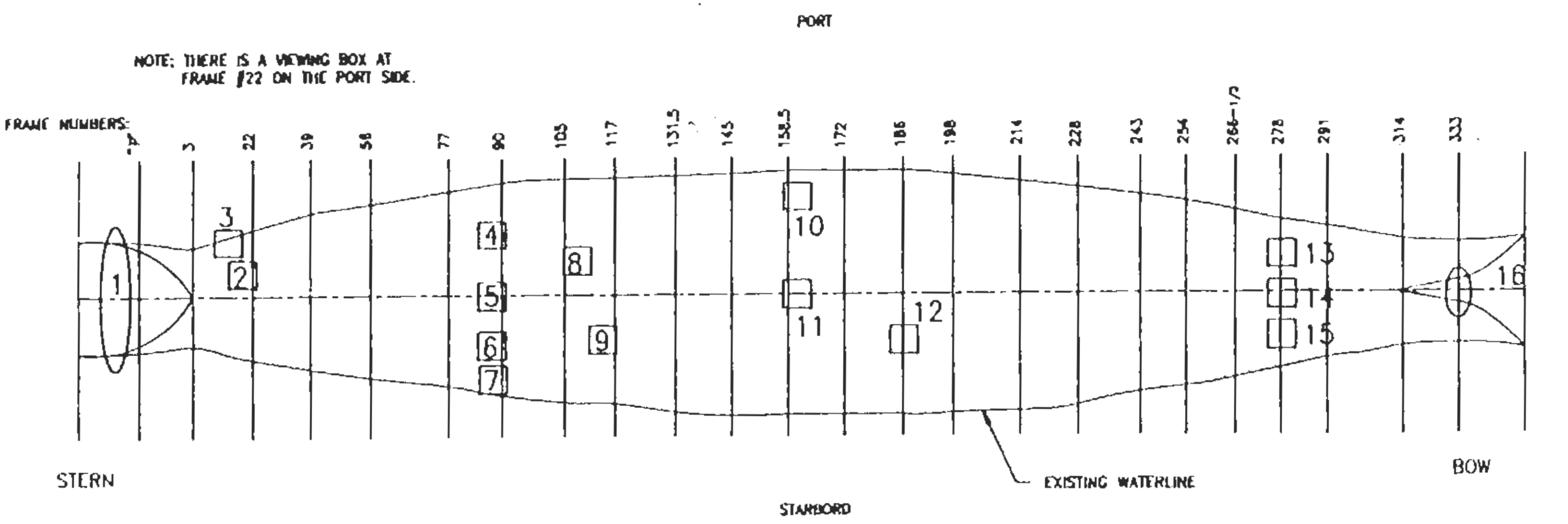
3.1.12 Inspection Location #12: Starboard side, Frame 186, starboard 45' of centerline.

3.1.13 Inspection Location #13: Port side, Frame 278, port 25' of centerline.

3.1.14 Inspection Location #14: Centerline, Frame 278.

3.1.15 Inspection Location #15: Starboard side, Frame 278, starboard 25' of centerline.

3.1.16 Inspection Location #16: Bow, Frame 333, centerline.



INSPECTION LOCATION OVERVIEW

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QUEEN MARY SHELL EXPANSION
FOR
CITY OF LONG BEACH

NO SCALE NOVEMBER 1992

3.2 LOCATION AND CLEANING METHODS

3.2.1 The inspection locations were identified and located with the grid system used to perform the cathodic protection survey. The hogging lines were placed at predetermined frames and the actual inspection location was located by referencing the transverse marking tags on the hogging line. For example; Inspection Location #15 was identified by placing the hogging line around the girth of the ship at Frame 278 and the inspection location was identified by the divers by locating the tag on the hogging line that was 25' to the starboard side of the ship's centerline or keel.

3.2.2 Each 10' x 10' inspection location was cleaned with a hydroblaster. A hydroblaster consists of an underwater gun which is held and operated by the diver and is supplied through steel braided hose from a 10,000 psi, 32 gpm pump located on the surface. IDS hydroblasters are capable of cutting concrete and steel.

It was initially thought that each inspection location would be cleaned to bare metal prior to inspection. However, shortly after the cleaning began, it was discovered that much of the ship's bottom paint was intact and firmly attached to the shell plating. Consequently, the entire inspection location was thoroughly cleaned but any firmly attached bottom paint was left intact.

3.3 INSPECTION AND DOCUMENTATION METHODS

3.3.1 Visual - Each location was visually inspected for pitting, cracks, metal condition, rivet condition, weld condition, coatings and any other visually apparent information. The diver's visual observations were recorded by the diving supervisor as they were given.

3.3.2 Ultrasonic Thickness Gauging - A minimum of 15 thickness gaugings were taken at each inspection location. The gaugings were recorded by the diving supervisor as they were taken.

3.3.3 Magnetic Particle Inspection - Magnetic particle inspection was randomly performed on several welds located at sea chests and the viewing box. Additional magnetic particle inspection would have been conducted if suspect welds or areas of fatigue had been identified.

3.3.4 Rivet Head Measurements - A minimum of 15 rivet head diameters were measured at each inspection location. Measurements were taken with calipers.

3.3.5 Pit Depth Gauging - Significant pits found at the inspection locations were measured with a manual pit gauge.

3.3.6 Documentation - All inspection locations were video taped during the diver's visual inspection. Sample photographs were also taken at each location. Diver's comments, pit gauging, ultrasonic measurements, rivet head diameters, magnetic particle observations and cathodic potential measurements were all recorded by the Diving Supervisor on appropriate report forms.

SECTION 20

INTERNAL INSPECTION

20.1 GENERAL

Previous inspection reports prepared in 1987, 1989, and 1990 all discuss serious deterioration of the internal hull structure. Due to the presence of water and contaminants in the bilges of the machinery spaces and shaft alley, the extent of deterioration in this after part of the ship could not be determined. The latest inspection report and repair cost estimate, produced earlier this year, after the bilges aft had been dried out, confirms heavy corrosion in this area, but gives no quantitative report on material loss. We were also informed by engineering personnel aboard the ship that a white substance surrounding some rivets and along some plate seams was suspected to be salt left from seepage of sea water into the hull.

20.2 INSPECTION DESCRIPTION

While our scope of work did not specifically include any internal inspection of the ship, we chose to perform an isolated spot inspection of the shaft alley in order to better understand the findings given in the previous reports and to gain a more complete understanding of the condition of the shell plating and rivets we were inspecting outside the ship.

20.2.1 Inspection Methods and Locations

The inspection was confined to the shaft alley located between bulkheads 21 and 51. Within that compartment, the following inspections were performed:

a. Samples of rivet heads still protected with intact coatings, and rivet heads showing extensive rust flaking, were identified. Rivets in the seam just above and inboard of the starboard inboard propeller shaft, between frames 21 & 22 were selected of typical of the compartment. These rivets were measured for comparison, in order to quantify the amount of material loss.

b. Samples of the white powdery substance evident around some rivet heads was collected for laboratory analysis. The collection was taken along the shell seam rivets directly above the inboard starboard shaft between frames 24 & 25.

c. Shell plating showing heavy rust and scale was scraped clean near the plate edges using a stiff bladed putty knife. The typical thickness of scale was measured and a visual inspection of the plate thickness at its edge was performed. This inspection was performed in the same area as the rivet inspection between frames 21 & 22.

d. The longitudinal centerline bulkhead was inspected and measured as a typical example of heavy deterioration experienced by internal framing members which were, until recently, submerged in contaminated water. Areas of severe deterioration were visually located around the lightning holes about 10 feet above the keel between frames 34 & 36. Plating thicknesses were measured at a lap joint where coatings were still intact and compared to thickness measurements around the periphery of lightening holes in way of heavy corrosion.

20.2.2 Inspection Findings

Shell rivet heads, showing heavy corrosion, have lost about 78% of their original material. The rivet shank is visible at the top of the head and appears to also have lost some material. The base of the rivet head still maintains the same diameter as the intact head and appears to be tight to the shell plating. Approximately 50% of the rivet / rivet head shear area is still intact. See the rivet inspection drawing at the end of this section.

The white substance collected from around rivet heads was found to contain zinc carbonate.

Scale and rust was removed from the shell plating in thicknesses up to 3/16". The exposed plating, while still retaining fine rust did not exhibit pitting any greater than 1/16". Remaining material at the lap joints appears to still be at least 7/8".

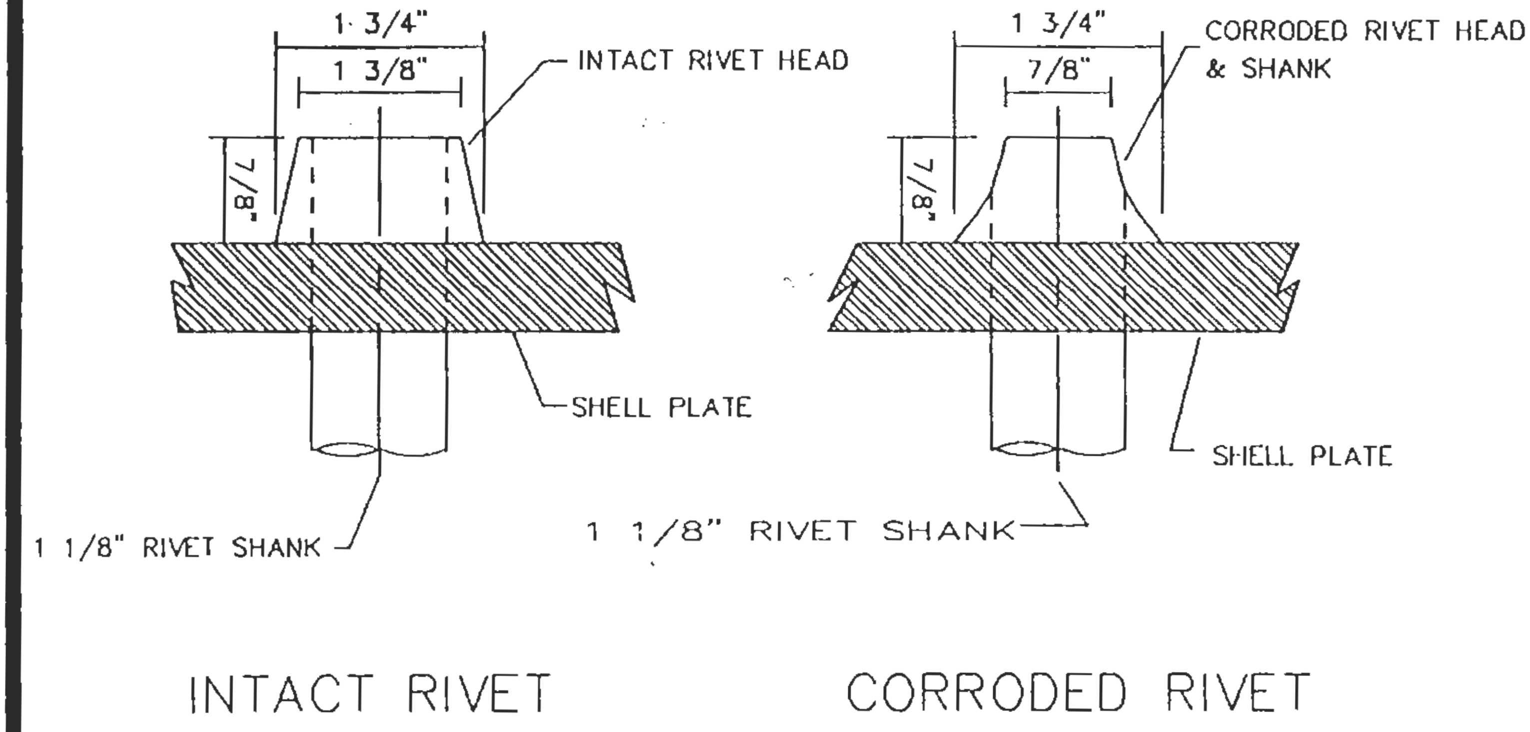
The centerline longitudinal bulkhead and various internal framing members are greatly corroded as indicated in previous reports. The bulkhead inspected is typical of this corrosion. Based on dimensions taken at a well coated lap joint, the plating appears to originally have been 3/8" thick material. Micrometer readings around the periphery of the lightening holes yielded thicknesses of 5/16" to 3/16" with pits further reducing this in some areas. The sheets of rust and scale removed measured about 1/4".

20.2.3 Conclusions

The internal visual inspection, in combination with the above data, yielded the following conclusions:

The compartment is essentially dry at this time with some minor amounts of moisture remaining in isolated pockets. There is no sign of movement of rivets or movement between shell plates. Shell seams and rivets are not leaking at this time and probably have not leaked in the recent past as there are no signs of weeping, nor of corrosion emanating from between the rivet heads and the shell plate. It appears that the severe corrosion was caused by the water which was purposely put into the compartment or allowed to enter there from piping and deck leaks.

Despite the fact that the internal structure has suffered extensive deterioration, there is no sign of structural failure in the form of plate or frame buckling or rivet separation.



INTERNAL RIVET INSPECTION

QUEEN MARY NOV 5, 1992

PK MARINE

SECTION 21

EVALUATION AND RECOMMENDATIONS

21.1 EXTERNAL HULL

21.1.1 Evaluation - Based on the sample data obtained through the random inspection methods utilized, the external shell plating, rivets, and welds below the waterline appear to be in good condition and are not currently experiencing significant deterioration. This is evidenced by the fact that many of the pits observed in plating and rivet heads still maintain the coatings applied when the ship was drydocked during conversion in 1969-71.

a. Shell Plating - The shell plating thickness was gauged at more than 240 points, in groups of 15 or more, at 16 locations on the shell. Thicknesses ranged from over 0.50" to 1.29", and averaged about 7/8". These thicknesses meet or exceed those currently required by the American Bureau of Shipping for deep tank bulkheads subjected to the same hydrostatic head currently experienced at the keel of the Queen Mary. A single point in inspection area 1, on centerline near the waterline at the stern, was gauged at 0.26". This reading is believed to be in way of a joint where the plate edge was beveled and thus not an indication of excessive corrosion in this location. All other readings in this inspection area exceeded 0.50".

Although the shell plating is covered with pitting, the pitting size averaged about 1/16" deep and does not present a threat to the integrity of the hull. As mentioned above, most of the pitting observed had occurred prior to the last drydocking of the ship as evidenced by the fact that the pits are filled with paint.

All lap joints were found to be in good condition with little or no signs of corrosion. The shim stock sandwiched between the lap joints was found to be intact and also in good condition where observed.

A visual inspection of the splash zone, (that area at and just above the waterline) indicated that, while extensive deterioration does not appear to have take place, this has recently been an area of active corrosion. It was noted that coincidentally with our inspection, a crew was engaged in sand blasting and recoating this area. This treatment will arrest the recent rate of corrosion.

b. Rivets - A minimum of 15 rivet heads were visually inspected and measured at each inspection location. The exterior rivet heads are countersunk into the shell plating. Although some of the rivet heads were severely corroded, all rivet heads measured approximately 1 3/4" in diameter. The majority of rivet heads which were severely corroded appear to be the result of corrosion which took place prior to the last drydocking. As with the shell plate pitting, the pitting on the rivet heads is filled with paint and the pitting does not appear to have progressed significantly further.

Several rivets, in the splash zone, were inspected with radiography (X-ray) to determine the amount of shank remaining on the rivets. The shanks appear to be approximately 1-1/8" in diameter which correlates with the original shank size as specified on original construction drawings. No significant gaps, which would indicate shank deterioration, were found between rivet shanks and shell plating. The small gaps visible on the x-rays are common for rivets which were driven hot and contracted as they cooled.

c. Seachest Closures - Seventy eight seachests in the hull have been blanked off with welded, or welded and bolted, boxes. These range in size from 12 inches in diameter up to 8 feet by 8 feet square. Three of the largest were selected for inspection. All three seachest blanking boxes and surrounding shell plating were found to be in good condition. Although some of the welds which connect the blanking boxes to the hull are randomly pitted, nothing was found to indicate a potential for structural failure.

Evidence was found of former sacrificial anodes on the closure boxes. These have been consumed over time, leaving these boxes unprotected.

d. Propeller Viewing Box - The area of the viewing box inspected was found to generally be in good condition. Thickness readings ranged from 0.54" thick on the viewing box to 0.86" or thicker at the surrounding shell plating. the weld quality was found to be poor and contributing to undercutting and crevice corrosion in the toe of the weld. Magnetic particle inspection of sample areas of these weldments indicated that no cracking has occurred. It can be concluded that, for the protected environment occupied by the ship, these welds are adequate and in no danger of catastrophic failure.

e. Stern Tube - One stern tube and surrounding shell plating was inspected and found to be in good condition, consistent with the findings in other shell plating areas throughout the ship.

21.1.2 Recommendations

a. Cathodic Protection System - Maintain the impressed current cathodic protection system currently in use on the ship's underwater parts. Except for certain shadowed areas, this system is providing adequate protection for the ship's underwater steel surfaces.

b. Sacrificial Anodes - Replace the depleted sacrificial anodes on seachests and install additional sacrificial anodes in the areas which are now shadowed from the impressed current cathodic protection system.

c. Existing Marine Growth - Leave the existing marine growth intact. This is providing a relatively uniform layer of protection to the hull.

d. Splash Zone - Monitor and maintain the coating system currently being applied to the splash zone. This area is constantly subjected to wetting and drying, heating and cooling, and thus tends to crack coating systems. Since it is not constantly submerged, it is not protected by the cathodic protection system. Once the coatings are cracked, this action allows moisture to penetrate under them and start the corrosion process again. When evidence of this breakdown is observed, the area should be cleaned and recoated.

e. Future Drydocking - If the ship is drydocked in the future, we recommend that all coatings and diver applied splash zone compound be stripped from the underwater hull. The entire wetted surface area of the hull should not be recoated, but left bare steel.

21.2 INTERNAL HULL

21.2.1 Evaluation

Given the protected environment in which the ship is floating, the internal structure does not appear to be in imminent danger of failure. If the corrosion process inside the hull, particularly in the areas showing severe wastage, is arrested at this time, the remaining hull structure should be sufficient to keep the hull intact, while floating in her protected environment, for at least the next three to five years. An engineering analysis, based on actual remaining material thicknesses obtained through gauging of internal members, and closer rivet inspection, should be performed before such time that this area is subjected to the localized forces associated with drydocking.

21.2.2 Recommendations

The above evaluation is predicated on the accomplishment of several preventive maintenance measures which must be initiated immediately. These measures, all of which can be performed with the ship in the water, at her current mooring, will ensure that the deterioration is arrested and that the areas of greatest deterioration are identified and repaired. The installation of a bilge system is listed last as that is where it fits in the logical progression of the recommended work. It must be emphasized however, that it is vital that some type of bilge pumping system, no matter how temporary, be installed immediately so that the bilges can be dried out and maintained while other work is in progress.

a. Clean-Up - Remove all scrap material and bilge sludge from all compartments showing deterioration. Sand blast all internal steel plate, shapes, and rivets in way of failed or missing coatings.

b. Damage Assessment - Perform an engineering study, including non-destructive testing, of the most heavily damaged internal parts of the ship. Where significant material has been lost, determine the scantlings necessary to maintain structural integrity in the ship's current environment and when drydocked. Determine the minimum rivet head material necessary to prevent rivets from pulling out.

   Perform floodable length and damaged stability calculations to determine the number of main transverse watertight bulkheads and the height of the bulkhead deck necessary to protect the ship from catastrophic flooding. Determine the appropriate capacity for a bilge pumping system.

c. Repairs - Perform internal structural repairs as found necessary by the engineering study. This may involve cropping out some internal structural members and welding in replacement pieces. Ring welding of some rivets may also be necessary. Recoat all interior steel surfaces with a new paint system.

   Install or restore the necessary watertight bulkheads up to the newly designated bulkhead deck.

   Install a bilge high level alarm system and a bilge pumping system for all watertight compartments. Cut limber holes as necessary in all non-tight structure to ensure drainage to the bilge suctions.