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SHIP ACCIDENTS AND DISASTERS

21 AUGUST 1979 (FOUO 21/79) 1 OF 2

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21 August 1979

USSR Report

MILITARY AFFAIRS

(FOUO 21/79)

Ship Accidents and Disasters

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ANNOTATION

[Text] The book systematizes materials on accidents and catastrophes of surface ships of navies of the capitalist countries which occurred as a result of fires and internal explosions, collisions, grounding, and the action of storms. Measures which are conducted to increase the survivability and safety of ships are shown.

The book is intended for shipbuilders and seamen, can be used by students, and is also of interest for a broad range of readers.

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FOREWORD

[Text] Sea-going and operational (combat) properties of ships are usually determined under laboratory conditions on models, in the course of full-scale tests of the ships and their equipment, and using calculations. However, this is not enough. The quality of the personnel and the stage of their preparedness for the use and operation of the ships may not be completely disclosed during the development and testing of ships. Errors and favorable aspects of a ship and crew (the "man-equipment" system) are learned most completely during practical sailing and service. The weak aspects of people and equipment are exposed and stand out in boldest relief during accidents.

Consequently, one of the most effective methods for discovering shortcomings (positive aspects) of ships and crews is the study of accidents.

The study of ship accidents permits us to substantiate conclusions for the improvement of ship technical and design elements, for improving their sea-going and operational (combat) qualities, and to make useful recommendations to improve the ability of ships crews and increase their discipline and organization. As experience shows, the main reasons for the majority of accidents and catastrophes of ships are rooted namely in the errors and oversights of seamen and shipbuilders.

The requirements for the design and construction of ships were improved as were the manuals, rules, and instructions for their use on the basis of lessons from accidents and catastrophes. Thus, for example, the capsizing of the torpedo boat "Tomoduru" served as the impetus for a review of the stability standards of the main classes of Japanese ships which were considered in the construction of new ships for the Japanese fleet prior to World War II and during the war. Fires on the carriers "Oriskany," Forrestal," and "Enterprise" forced the naval authorities of the United States to adopt a number of radical measures to increase the fire safety of carriers and other classes of ships. After the loss of the nuclear submarine "Thresher" much was changed in the requirements for the design and construction of the U.S. submarine fleet as well as in the manuals on navigation in submarines and their use.

In the commercial fleet, the loss of the "Titanic" was the impetus toward the elaboration and adoption of the first "International Convention on the

Protection of Human Life at Sea," and the "Andrea Doria" catastrophe was the impetus for a regular review of the convention which was in effect and its adoption in new form.

The conclusions which were drawn from the materials on accidents and catastrophes became the points of departure not only for the elaboration of measures and recommendations of a practical nature, but also for the development of shipbuilding theory and other naval sciences.

The study of the accident of the "Rusalka" marked the start of S. O. Makarov's many years of study by which he formed the basis for the study of a ship's unsinkability, while the loss of the "Victoria" served as the occasion for his development of a number of practical scientific methods in the study and improvement of ship unsinkability.

In his numerous investigations in the theory of shipbuilding, Academician A. N. Krylov often turned to various instructive accidents. It was he who wrote a number of works especially on the accidents of ships which subsequently were combined in the work, "Several Cases of Accidents and the Loss of Ships" [90].

At one time, many theoretical studies were conducted in connection with the capsizing of the ironclad "Kepten" [as transliterated]. The physics of the phenomenon of vessels mutual "suction" became a subject for study on the basis of the case of collision of the cruiser "Hawk" with the liner "Olympic." Important scientific-experimental studies were conducted in the field of ship strength in connection with the break-up of the destroyer "Cobra." There are a great many such examples. Some accidents and shipwrecks became literary classics and became part of the literature which discusses various questions in shipbuilding and navigation.

Soviet literature contains no books in which a scientific-technical analysis of the facts concerning accidents and catastrophes of today's warships would be accomplished. The book by K. P. Puzyrevskiy, "Damage to ships, Damage Control, and Rescue Work" [92] describes events from the period of World War II.

Meanwhile, it is namely during recent decades that a great number of accidents and catastrophes occurred on foreign ships (without combat effects) which must be studied to extract useful lessons from them. Data on such accidents are scattered among various foreign sources, primarily periodicals which frequently have a contradictory and tendentious nature.

Books on this subject which have been published abroad during the last 10-15 years cannot satisfy the Soviet reader. For example, K. C. Barnaby [97] and H. W. Baldwin [96] examined only individual cases of accidents with warships and merchant vessels. Furthermore, these books contain facts which do not go beyond the limits of World War II. The two-volume publication by C. Hocking [102] has a reference-book nature and records (with a number of inaccuracies and distortions) cases of the loss of ships and vessels during the period of 1824-1962. The interesting book by F. Rushbrook [4] throws light on the questions of fires and fire protection on merchant vessels alone, while P. Padfield [71] examined only individual accidents which occurred during collisions of ships and vessels without their systematic analysis.

To a certain extent, this book fills the gap in this area. It systematizes and generalizes the experience of accidents and catastrophes of surface ships in the navies of capitalist countries which occurred as a result of fires and explosions, during collisions, and as a result of running aground and the effects of storms.

Using specific examples, the author analyzes the reasons for accidents and the nature of the damage to ships, the design features which ensure their survivability, the actions of the personnel in the struggle for survivability, and in some cases the organization of salvage operations and the repair of damaged ships. Where possible, in the analysis of each type of accident an evaluation is made of the ships' design and actions of the crew under emergency conditions as well as of the measures which are being adopted in foreign fleets to increase ship survivability and safety.

The book investigates accidents and catastrophes of all the basic classes of surface ships as well as of auxiliary naval vessels. Chapters I, II, and III cover individual types of accidents, while Chapter IV sums up some results and draws conclusions about ways to reduce the accident rate and increase ship safety; characteristics of 518 accidents and catastrophes are presented, on the basis of whose examination an analysis is made. They embrace all types of surface ships of the last several decades.

The analysis of accidents involving aircraft carriers is made for the last 25 years, and involving ships of other classes--for 50 years. Individual instructive cases of accidents which occurred earlier are examined.

The appendices provide brief information about ships which were lost from the beginning of the century up to the present--individually by type of accident.

Soviet and, primarily, foreign sources were used in writing.

The elements of ships which are presented in the book were taken from "Jane's Fighting Ships" and, in individual cases--from other foreign sources (see the bibliography) as well as from Soviet reference publications which served as the basis for the Russian transcription of the names of ships and vessels.

In accordance with the information which the author had at his disposal, the following are indicated: for surface ships--the normal displacement, primarily for ships built prior to World War II, and complete displacement for ships built later; for submarines--the numerator gives the displacement while surfaced and the denominator--while submerged. Their year of going into operation is shown for all ships. The capacity in register tons is presented for merchant and auxiliary vessels.

The geographic names of the places of accidents and catastrophes are presented as they were at the time of the accident; the writing of places for postwar years is taken from data in Soviet reference books, "Morskoy atlas" [Marine Atlas].

The author expresses his profound gratitude to B. A. Kolyzayev and A. M. Vasil'yev who, while reviewing the manuscript, expressed extremely valuable critical remarks which permitted an improvement in the quality of the book. The author expresses his great gratitude to S. Ya. Levina for assistance in working on foreign sources.

[Excerpts] 8. Fire and Explosions on the Carrier "Essex" During the Landing of an Airplane

The American attack carrier "Essex" (38,500 tons) was cruising not far from the coast of Florida in 1959 when a big fire broke out on it.

The pilot of a fighter erred in estimating the moment of landing. Receiving the signal prohibiting the execution of a landing on the flight deck, he gave the airplane the gas and began to climb but, deviating from the line of the landing area he grazed an airplane standing on the deck with the right wing plane. As a result of the blow, the airplane which was in the air turned and, engulfed by flames, tore into a group of airplanes which were disposed on the flight deck along the side of the ship. A fire accompanied by individual explosions broke out on the carrier--tanks with fuel and oxygen cylinders exploded. The explosions caused such a high temperature that the metal fragments of the airplanes were welded to the ship's deck.

The tractors hastily threw the airplanes which were engulfed with flames overboard. In order to prevent the fire's further spread over the flight deck, the carrier was turned with its side to the wind. But the fuel which had ignited flowed into the lower compartments of the ship, including the hangar and causing new loci of fire. The carrier crew eliminated the fire in several hours.

Two men died as a result of the fire and explosions while 21 men received burns and injuries. Many airplanes were destroyed or put out of action. The ship received considerable damage and it was sent to Norfolk for emergency restorative repairs which lasted for several months.

In justifying the accident which occurred on the "Essex," the American press referred to the fact that the ship had become "obsolete" and must be replaced although rather expensive modernization work had been performed on it as well as on other carriers of this type only several years prior to this accident.

In this case, of course, it is not a matter of "old age," but of poor training of the flight personnel and the incompetent organization of takeoff and landing operations of the carriers. For accidents during the landing of aircraft on carriers, just as during takeoff, are frequently repeated, in which regard on ships of the latest construction.

16. Consequences and Lessons from the Fire Disaster on the carrier "Forrestal"

Only several months had passed since the big fire on the "Oriskany" when a new fire catastrophe broke out in the same Gulf of Tonkin. This time, it was the attack carrier "Forrestal" (1955, 76,000 tons, Fig. 7 [not reproduced]) --the flagship of a carrier division and the first of the ships of this class to be built by the Americans after World War II.

At one time, the name of this ship was extremely high-sounding, especially in the United States. For a rather large series of attack carriers was constructed from the model of the "Forrestal." Eight such ships were put into operation in the U.S. Navy with several variations during a decade and a half. Thus, during the first postwar decades the "Forrestal" was a kind of symbol of the striking power of the biggest U.S. surface ships and, really, of the other capitalist powers.

But at the end of the 1960's, in connection with the disaster which occurred, the carrier acquired an extremely sad reputation. During these years, it had already began to "symbolize" more naval tragedies and calamities, especially in the U.S. carrier fleet which, in the postwar years, abounded in fires and explosions which occurred without combat effects on the ship.

Prior to departure for the shores of Vietnam from the base at Norfolk to take part in combat operations, the "Forrestal" completed an eight-month major overhaul and modernization costing about 50 million dollars, which amounted to approximately one fourth of its construction cost. After completion of the repair and modernization work, the "Forrestal" was considered a completely modern ship technically. In the course of the repair, special attention was paid to improving the ship's fire-extinguishing means.

The situation concerning its crew was somewhat different. In fact, during the entire time of its existence the "Forrestal" was not required to participate in combat operations prior to 1967. During 12 years of service it was part of the Atlantic Fleet and sailed primarily in the Mediterranean Sea, undergoing only instructional training. Now it was to participate in combat operations where there was a need for other approaches and other training than on training cruises. Did the crew of this ship have such training?

In the opinion of the commander of the 2d Carrier Division, U.S. 7th Fleet, the personnel of the "Forrestal" did not have sufficient training for the conduct of combat operations.

However, let us turn to the circumstances of the fire disaster which developed.

On 29 July 1967, the "Forrestal" had been maneuvering in the Gulf of Tonkin for five days already, being 60 miles from the coast of the DRV and preparing for barbarous bombing. The day was bright and sunny in the gulf. The carriers "Oriskany" and "Bonhomme Richard" were near the flagship. The destroyers "MacKenzie" and "Rupertus"--both Gearing types, were protecting the carriers' zone of action.

On that morning, one group of airplanes had already been catapulted from the "Forrestal." A second group was now preparing for launching; it was almost completely formed up and prepared for takeoff. This group included 12 carrier-based aircraft of the "Skyhawk" type, 7- "Phantom" fighters-interceptors, and 2 attack-reconnaissance aircraft of the "Vigilant" type--altogether 21 aircraft. Preparations for takeoff had been completely accomplished on 12 airplanes of this group: they had been fueled, supplied with ammunition, the pilots were at their places in the cockpits, and the aircraft engines had been started. Final preparatory operations were concluding on the remaining aircraft which had also been fueled and armed with ammunition. Everything "was taking its natural course."

Suddenly, a flame flared up in the stern portion of the flight deck where the airplanes which had prepared for takeoff were located. The exact moment of the blaze was recorded--1053 hours. Various versions exist concerning the reason for the outbreak of flames. According to one of them, the fire broke out from an unintentionally launched "Zuni" air-to-surface rocket which was suspended beneath a "Phantom." During its motion, the rocket struck the suspended fuel tank of one of the "Skyhawks" and the fuel which was poured over the deck ignited from the rocket's jet. According to another version--due to an oversight by the personnel, a suspended fuel tank fell on the flight deck, the fuel from which ignited and spread over the flight deck; under the influence of the flames, the warhead of the "Zuni" rocket was separated and the fuel tanks caught fire. One way or another, both versions confirm the fact that a "Zuni" rocket exploded and influenced the subsequent development of the fire. In some publications the fact of the unintentional launching of the "Zuni" rocket is attributed to the failure of its "safety mechanism."

The first measures which were adopted to eliminate the fire which had broken out using the main water line and deck foam generators proved to be ineffective. Because of the crowded disposition of the airplanes on the flight deck (Fig. 8) [not reproduced] the flames quickly engulfed almost the entire group of airplanes. Fuel tanks began to burn and aerial bombs and other ammunition began to explode. The fire soon spread over the entire stern portion of the flight deck. Aerial bombs weighing 340 and 450 kg exploded on the deck one after the other. The exploding airplane fuel tanks gave off a black smoke which spread over the flight deck and penetrated into the interior compartments of the ship.

Killed and injured appeared after each explosion. Many fire-fighters were killed or put out of action as a result of the first explosions. Fire-fighting equipment was damaged by the fire and fragments. Some of the crew members were thrown overboard by the waves of the explosion while others jumped off the blazing carrier to save themselves from the raging flames and exploding bombs and rockets. Seriously wounded and even killed were among those thrown into the sea since the height of the ship's freeboard exceeded 18 meters. Many of the pilots were unable to save themselves from the airplanes burning on the flight deck.

But the majority of the crew remained aboard the ship and, from the very first minutes the crew waged an intensive struggle against the fires and explosions.

Numerous press reports not only in the United States, but also in a number of other countries including Great Britain, France, Italy, and Japan, confirm that the crew's actions in the course of the catastrophe were energetic and, at times, selfless. The airplanes on the flight deck which were not engulfed by flames were dragged from the stern to the bow of the ship. Bombs and missiles were disarmed by removing the fuzes from them. One of the basic procedures which was employed to prevent successive explosions was the dumping of the ship's and aviation ammunition overboard. There were instances where people descended through holes in the flight deck into the "inner hell" to drag out the smoking bombs from inside the ship, disarm them, and throw them overboard. People turned the water hoses on one another in order to cool and prevent the ignition of clothing and footwear. Meanwhile, the flame penetrated more and more into the ship's compartments. On the hangar deck, seamen fought the fire in the darkness, removing bombs and missiles from the airplanes by feel and dropping them overboard.

Since passage into the hangar from above was virtually excluded, holes were cut out in the flight and gallery decks and from the sides to penetrate into the hangar compartments, for which oxyacetelyne equipment was used. More than 10 holes were cut in the flight deck alone; the opportunity was opened to lead people out of the interior compartments and use them to fight the fire. Previously, the attempt was made to extinguish the fires in the lower compartments of the ship with water through the holes in the flight deck. The hot bulkheads were continuously cooled with water so that it would be possible to accomplish urgent work. Many cases where the injured and the burned worked with fire hoses to localize the zone of the fire were noted.

The deck became slippery from the foam, greatly hampering the fighting of the fire which was spreading through the ship more and more. But the chief difficulty was created by the smoke which was so dense that visibility, even that attainable using a light, was no more than 0.3-0.4 meters. A favorable role under these conditions was played by respiratory equipment without which it would have been impossible to work in the smoke. However, the lenses of the equipment frequently fogged over and people could hardly see anything. Fire hoses were shifted from the bow of the ship to the stern, but they were put out of operation from the effects of fire and fragments. Carbon dioxide fire extinguishers were employed rather successfully to quench the fire on the airplanes.

The fire was fought not only with the men and equipment of the damaged carrier. The "Oriskany" and "Bonhomme Richard" as well as both escort destroyers--the "MacKenzie" and "Rupertus"--came to her assistance. Stopping the launching of their own airplanes, the carriers rescued victims with helicopters. The destroyers approached almost up to the very sides of the "Forrestal" (up to 3 meters) and directed streams of water at it from their fire hoses.

In fighting the fire, many mistakes were made which were connected primarily with the crew's inexperience. Emergency (alternate) paths of evacuation were not used: either the crew did not know them or they had been forgotten. Since a large part of the experienced fire specialists perished in the first moments of the fire, the matter of saving the ship was placed in the hands of people who had absolutely no experience in fighting fires. It was for this very reason that little was done to localize the fire which engulfed more and more bombs and missiles which were on the flight deck, and newer and newer explosions shook the ship.

The order to close the dividing doors between the carrier's compartments was given after a long delay (eight minutes after the start of the fire). This also helped the fire to spread through the ship.

One of the big mistakes was that the untrained fire teams often reduced to naught the actions of the people working alongside them. Thus, for example, while some sprayed protein foam over the flight deck to extinguish fuel fires, others washed this foam away with water when working with water hoses. Thus, precious time was lost and the fire continued to spread through the ship.

The ship's command did not organize the fire-fighting properly.

Despite all the measures which were adopted, the fire penetrated into the ship more and more and spread in the compartments below the hangar deck. The fire's development was also furthered by the ignition of bedding and the crew's clothing.

After several hours, by means of exceptional efforts the crew succeeded in localizing the main loci of fire on the flight and hangar decks, blocking the fire's path to the middle and fore parts of the hangar where the armed airplanes were located. But the fire between these two decks raged until the very evening. Ten hours passed before the fire began to die down gradually. It took more than a day to extinguish it completely--at 1230 hours on the following day. However, the fight with the smoke continued. A large quantity of harmful gases accumulated inside the carrier. They had formed during the fire and could be eliminated only after three days. At the same time, the crew was engaged in cooling the hot sections of the decks and other structural elements.

As a result of the catastrophe, 134 men died while 62 were wounded. Twenty-six jet airplanes, 40* machines together with catapults and arresting gear, artillery armament, and various ship's equipment received considerable damage. The carrier's hull especially suffered: 6 of its 10 decks were damaged, especially the flight deck and structural elements located near it. Seven holes, some of them of rather large dimensions (Fig. 9) [not reproduced], were formed in the armored flight deck (with a thickness of 45 mm) from the explosions.

A general view of the carrier after the catastrophe looked as if it had been subjected to combat action (Figs. 10, 11) [not reproduced]. One of the

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* According to other data, these figures fluctuate somewhat in one direction or another.

"Forrestal's" officers noted that during World War II "kamikaze" pilots could not inflict such damage on a ship.

The material loss from the catastrophe was estimated at 140 million dollars (the cost of emergency repair of the ship itself was 14 million dollars).

For amounts of damage inflicted and human losses (according to the estimate of the Americans themselves) this catastrophe was the biggest in the postwar years among the sea catastrophes of the American fleet. Even the damage from the loss of the nuclear submarine "Thresher" in 1963, which was considered as a national disaster in the United States, was considerably less than from the catastrophe of the "Forrestal."

To eliminate the aftereffects of the fire, the "Forrestal" was first sent to Subic Bay (in the Philippines) to which it moved under its own power. According to the ship commander's statement, the carrier could develop a speed of 27 knots, in so doing using four of the eight main boilers. En route to Subic Bay, the "Forrestal" transferred many injured to the hospital ship "Repose" which was dispatched especially for this purpose.

During the passage, at least 20 specialists from various facilities worked on board the "Forrestal." They determined the volume, times, and cost of restoration work even before the ship arrived at the repair base.

During the carrier's 10-day stay in Subic Bay, temporary repairs were made to the flight deck in addition to several repairs connected with ensuring the passage to the main base so that, "if necessary," the ship could perform takeoff and landing operations.

The "Forrestal" arrived in Norfolk, where the main repair was envisioned, only 1.5 months after the catastrophe. This was rather strange since usually damaged ships were not held up at sea but, on the contrary, every attempt was made to berth them as soon as possible to return the ship to action more rapidly. Why was there such a long delay in this case? The official version states that the "Forrestal" was given permission to visit several ports to pay tribute to the victims of the catastrophe and call upon their families. But actually, they had in mind delaying the ship's arrival at the base for the longest possible time, remembering that "time is the best doctor." But this policy of "delays" did little to help its ideologists.

Several thousand persons including reporters, motion picture cameramen, and representatives of the Navy and various authorities gathered on the shore to greet the carrier. The American press noted that the tremendous ship looked like a "gray mountain" and that not even a trace of its majesty and beauty remained. Meeting with the reporters, the carrier's commander praised the ship's construction and spoke of its crew's bravery--the ship was on the brink of being lost, but people saved it. However, nothing was said about the reasons leading to such catastrophic consequences which became a genuine calamity for many, many American families.

The carrier was repaired at the Navy dockyard in Norfolk. A considerable portion of the flight deck was replaced (Fig. 12) [not reproduced]. Eight hundred tons of armor steel were required for this. The aircraft elevators which were heavily damaged by 127-mm artillery pieces and other equipment were removed from the ship and repaired under plant conditions. The aircraft armament was completely replaced. At the same time, modernization work was accomplished on the ship, in particular on electronic equipment and missile-artillery armament.

Despite a number of special measures (assignment of a special group of engineers and workers numbering several hundred men, three-shift work, and so forth), the carrier's repair continued for about 10 months and it went into operation a year after the catastrophe. Then the "Forrestal" was assigned to the U.S. Atlantic Fleet and was sent to perform service in the Mediterranean Sea. The ship's crew was brought up to strength and its commander was replaced.

The "Forrestal" disaster caused a great public response. In many articles and publications not only were the big human sacrifices and material losses noted, which were the result of the fire on this ship, but also the low level of fire safety of carriers in general and the insufficiency of measures undertaken by the Navy to ensure it. Here, other accidents and catastrophes which occurred on carriers in recent years were recalled. Political and state figures spoke of the loss of U.S. prestige in connection with such catastrophes.

In the discussion which was conducted in the United States in the middle of the 1960's on how carriers should be constructed--nuclear or conventional--the "nuclear" viewpoint prevailed and the disputes seemed to subside. But they flared up anew in connection with the tragic events on the "Forrestal." Now, voices began to be heard in which doubts of the expediency of the further construction of this class of ships of such gigantic dimensions in general were sounded.

The new disputes did not shake the main course of the U.S. Navy's command, however, and the construction of new, big carriers continued even farther. It was only adjudged necessary to adopt urgent and effective measures to improve the fire safety of these ships.

Thus, it was the "Forrestal" disaster, which was the biggest among other similar catastrophes, that transformed questions of ensuring the fire safety of carriers into an extremely important state problem since, in the United States, the greatest significance is attached to these ships along with submarines. It was decided to establish a commission on an extremely high level to work out recommendations on this problem. Its composition included the highest authorities of the U.S. Navy and Air Force. Admiral J. Russell, who was called up from retirement for this purpose, was appointed chairman.

Before the Russell commission began its work the Chief of Naval Operations of the U.S. Navy, Admiral T. Moorer, gave it the following general instruction: "When explosion and fires occur nevertheless despite all various precautionary measures, it is important that we have rapid and extremely effective means to reduce damage, destruction, and the loss of human life to the minimum. Therefore, it is necessary to see that in combating explosions and fire the personnel are subjected to the minimum degree of danger" [38, p 7].

It should be noted that working along with this state commission was another which was engaged in investigating the reasons and circumstances for the "Forrestal" catastrophe itself.

The Russell commission analyzed the status of fire safety on U.S. carriers and adjudged it unsatisfactory. In this connection, Admiral Russell wrote: "We had 32 "Essex"-type carriers in World War II and 30 of them had serious damage, but none were lost because we had powerful fire-fighting means. During the past years, we have lost the ability to fight large fires in considerable measure" [24, p 26].

This judgement by Admiral Russell needs serious corrections.

First of all, only 24 rather than 32 carriers of the "Essex"-type were built. Of these ships, only 17 were put into operation during the war (and only 12 of them took part in combat operations), the construction of 7 carriers was completed in the postwar years, and one of them (the "Oriskany") was turned over to the Navy only in 1950. Thus, 30 "Essex"-type carriers could not have such serious damage as Admiral Russell stated.

Actually, not one of the "Essexes" was lost during the war. But what was the behavior of these ships with combat effects on them? Let us take several examples from the last stage of the war.

On 25 November 1944, two "kamikazes" dove on the carrier "Intrepid" in the area of the Philippines. A fire broke out on the ship causing it heavy damage, and it was out of action for several months.

On 21 January 1945 the carrier "Ticonderoga," also attacked by two "kamikazes" near the island of Taiwan, was heavily damaged. A big fire broke out on it and it was put out of actions for a long time. Losses were 140 men.

On 19 March 1945, the carrier "Franklin" received two medium-caliber aerial bomb hits in the area of the island of Kyushu. Fires and internal explosions broke out on the ship, in which regard the damage proved to be so heavy that it had to be towed to base, but restoration proved to be impossible. Losses on the carrier consisted of more than half the ship's crew: 832 killed and 270 injured.

On 6 April 1965 the carrier "Hancock" was damaged near the island of Okinawa from the explosion of an aerial bomb and ramming by one "kamikaze." A fire broke out on the ship; it received considerable damage and was put out of action for a long time. There were 72 killed and 82 injured on it.

On 14 April, the carrier "Intrepid" which had emerged from repair was again attacked by two "kamikazes" in the area of Okinawa. A big fire broke out and the damage to the ship proved to be so serious that it was necessary to send it off for repair again under shipyard conditions. Losses were 97 men.

On 11 May 1945, a "kamikaze" tore into the carrier "Bunker Hill," as a result of which it received considerable damage, was sent to the base for repair, and took no further part in the war.

All these were ships of the "Essex" type. The facts which are presented were taken from books by the American historian of World War II, S. Morison [91], and a combat admiral of the American fleet, F. Sherman [3] and can hardly be refuted by the admiral of the same fleet, Russell. But these facts, the number of which could be multiplied, refute rather than confirm Admiral Russell's conclusion concerning the high survivability and fire safety of "Essex"-type carriers during World War II.

By the way, comparing the "Essexes" with British carriers which operated in the Pacific Ocean at the same time, Admiral F. Sherman writes in the same book: "Although all British carriers were subjected to attack by 'kamikaze' airplanes, not one of them was put out of action thanks to their armored flight decks" [3, p 284]. This conclusion by Admiral Sherman concerning the significance of armored flight decks of British carriers, which pertained primarily to ships of the "Illustrious" type, was confirmed many times during the war. And you see, British carriers of the "Illustrious" type had a displacement several thousand tons less than carriers of the "Essex" type. Evidently, for this reason the Americans began to employ armored flight decks on all their attack carriers which were built after the "Essex"-type carriers.

Thus, from the fact that not one "Essex"-type carrier was lost during the war it does not at all follow that their survivability and fire safety were at a high level. The facts tell us just the opposite. For the "Forrestal" and "Oriskany" were not lost from fires either, while their fire safety was evaluated as unsatisfactory by the same Admiral Russell and his commission. Hence, it follows that the criterion of a ship's survivability in fires does not have to be its loss. Serious aftereffects are also possible for a ship in fires even without its loss. A classical example of this is the case of the "Forrestal." It should be added to this that the dozens of accidents on carriers of the "Essex" type which were connected with fires which occurred in the postwar years and their aftereffects do not tell of the high fire safety of these ships, either.

The commission acknowledged the basic reasons for the low level of fire safety of the American carriers to be the insufficient capacity of the fire-fighting equipment on the ships, poor training of the personnel, and insufficient organization of fighting fires.

Based on the lessons of accidents and catastrophes of carriers, primarily the "Oriskany" and the "Forrestal," the commission worked out a number of recommendations to increase the fire safety of this class of ships. The recommendations included construction, organization-technical, and general measures.

The basic recommendations of a construction nature are:

1) to develop and install on carriers more powerful fire-fighting equipment, especially on flight decks, where fire safety must be brought to the level of safety in hangars;

2) to incorporate on carriers a sufficiently effective remote-control fire-fighting system, especially on the flight deck;

3) to employ highly-effective flash-suppressing materials in fire-extinguishing systems on carriers; in particular, the possibility of drenching a large part of the flight deck with this material should be incorporated;

4) to incorporate more effective life-support and individual-protective equipment on carriers in order to provide the personnel with the capability to work in any compartments during fires; in particular, to have more powerful and numerous exhaust ventilation means to remove smoke from compartments and supply the personnel with individual oxygen apparatuses and equipment to protect the hands from hot objects;

5) to improve the methods and means for storing fuel and ammunition on carriers;

6) to devote special attention to questions of ensuring the fire safety of the airplanes which are on the ships;

7) to conduct a radical review of the existing communication and warning system on ships and to improve it in such a way as to bring it close to an actual situation on a ship when fighting fires.

The commission noted that some of the ammunition taken on board the carriers is not supplied to a sufficient extent with the necessary safety devices, as a result of which their unintentional triggering and explosion can and actually do arise. Although the commission did not write down a direct recommendation, it expressed the desire concerning the necessity to conduct work in the appropriate direction. Concerning this problem and referring to the example of the "Zuni" rocket whose explosion, in his opinion, was the source of the disaster on the carrier "Forrestal," Admiral Russell declared at a press conference in the Pentagon that he would like "ammunition to be made more reliable." "We need safer armament," he stated.

The second group of recommendations pertained to training the personnel to fight fires.

Noting that the fire on the "Forrestal" showed the importance of the "human" factor to ensure safety with all obviousness, the commission recommended:

1) devoting primary attention to safety questions and instructions everywhere and always, beginning with the first steps in instructing the personnel;

2) making more efficient use of reports of accidents on ships and informing personnel about accidents by a specially created U.S. Navy safety information center;

3) future commanders of carriers should not avoid questions of fighting fires but should become actively engaged in them, for which special on-the-job training is envisioned for their instruction in this important matter;

4) all aviation personnel on board a carrier, together with the ship's crew, should be involved in the process of ensuring the ship's safety, strictly delimiting the functions between them in this regard;

5) introducing rigid requirements in the fleets so that existing safety rules are strictly implemented at all stages and replacing some of them with new, more improved ones.

As general recommendations, the commission noted that there is a necessity for reorienting minds in regard to the safety of carriers since safety is often disregarded at the expense of direct effectiveness. All organizations and departments, military as well as civilian (industrial, scientific, fire-fighting, and others), in the opinion of the commission, should be used for the attainment of effective results in this area.

Although the Russell commission was not and really could not be a panacea in the solution of fire safety problems of carriers, its recommendations which are based primarily on a study of the experience of the "Forrestal" catastrophe were a certain beacon for the U.S. carrier fleet.

Judging from publications, this experience of the Americans is also used in other countries where aircraft carriers are in the inventory, in particular in Great Britain and France.

[pages 84-85]

The following lessons were carried away from the fire on the "Lafayette"-"Normandy":

1) welding and cutting should not be permitted on a ship until all combustible materials have been removed to a safe distance or, at least, until they are sufficiently protected so as to prevent their ignition when conducting hot work;

2) when a ship is in port, especially when refitting work is being performed on it, the presence of fire-fighting equipment which is powerful enough to fight fire and is always ready for action should be ensured. In particular, it is very important to ensure the standardization of hose connections in case the ship is in a strange port;

3) during the refitting of the ship, clarity in regard to organizing the fighting of fires should be envisioned, especially in designating responsible persons and the supervision of actions in fighting fire on a ship;

4) a special and well-trained fire-fighting team should be on the ship. It is necessary for preventive purposes as well as for the qualified fighting of a fire which breaks out;

5) continuous and strict monitoring of the conduct of hot work should be conducted on a ship which is being refitted;

6) any ship being refitted must be equipped with necessary and reliable equipment for communication, warning, and signalling;

7) smoke from fire on the upper decks should not be allowed to penetrate into the engine and boiler rooms, for which the skylights and so forth in these rooms should be closed immediately upon the outbreak of fire on the upper decks and all suction fans leading into these rooms should be stopped;

8) those participating in fighting the fire should use water to extinguish a fire exceptionally economically, keeping in mind the danger of the extreme filling of the ship with water and the possibility of its loss of stability;

9) to reduce the threat of the ship's capsizing when fires are being extinguished, a system for the removal of "fire" water from it should be envisioned.

10) all fire doors around the center of the fire should be closed immediately after its outbreak and should be opened only to service the minimum needs of the groups of people which are fighting the fire.

These conclusions, which were drawn on the basis of experience from a fire which, in essence, occurred on a merchant ship are evidently also valid in regard to warships for the most part.

One more lesson, which consists of the following, can be carried away from the experience of the fire on the "Lafayette"-"Normandy." It is not enough to incorporate a high technical level of fire safety in the design of a ship and it is not enough even to realize it during construction. For the actual ensuring of fire safety it is necessary to observe fire safety rules on the ship and have constant readiness of available fire-fighting technical equipment for action and the personnel's excellent knowledge of their ship--its basic qualities, equipment, the arrangement of compartments, and state of preparedness and readiness of the crew to fight fire.

Comparatively not long before the "Lafayette" catastrophe, ships were lost under similar circumstances. Thus, for example, in December 1931 in Newport News, Virginia, the British cargo-passenger steamship "Segovia" (9,500 tons) capsized at the outfitting quay as a result of the extinguishing of a fire. The flooding of the upper parts of the ship was caused by its loss of transverse stability, and it lay on the right side with a list of 80 degrees at the quay, not sinking completely due to the comparatively shallow water. Thus, the "Lafayette" almost repeated the sad experience of the "Segovia" on an increased scale. Another example can be provided by the French liner "Paris" (34,570 tons) which sank under similar circumstances in Le Havre in April 1939; all people on board perished. Unfortunately, these and other measures were not considered by the American fire-fighters who sank the biggest military transport in their own waters, thereby inflicting considerable loss on the military potential of the Allies during the war.

[pages 86, 89-90]

3. Explosion of the Military Transport "Fort Stikene" (Catastrophe in Bombay)

In April 1944, Bombay was overcrowded with ships. Many of them were loaded with explosives which often were stored together with other explosive and inflammable cargoes. At that time, three warships of the Indian Fleet were also at dockside.

On board the British steamship "Fort Stikene" (the ship was a British version of the "Liberty" ships, 7,142 tons) which had been moored at one of the Bombay piers, 3,000 tons of cotton were stored along with 1,400 tons of explosives and ammunition. In addition, 155 ingots of gold, whose value was estimated at 5 million dollars, were loaded on the ship. The gold was intended for India to stabilize its currency. The "Fort Stikene" arrived in Bombay from Karachi on 13 April. Its unloading was begun on the morning of the following day.

The total material loss from the catastrophe was estimated at 1 billion dollars. As regards human losses, according to official data the dead and missing numbered 1,500 while 3,000 people were injured and burned. It is difficult to estimate the total loss inflicted on the Allied war machine and the effect of the catastrophe on the course of the war: ammunition, explosives, and various items of weapons and equipment which were destroyed during this calamity and which were intended for Burma and the Allied troops which were operating in the Pacific.

The commission which investigated the reasons and circumstances of the catastrophe adjudged the storage of cotton on the ship together with explosives incorrect. A burning cigarette was adjudged to be the most probable reason for the start of the fire.

Among the factors which contributed to the development of the fires and the outbreak of explosions, the commission noted the following:

1) the absence of unified and firm centralized direction in organizing the fighting of the fire and the coordination of all its participants' actions;

2) the inability of responsible personnel to understand the entire seriousness and danger of the situation with the start of the fire's outbreak and subsequently with its development;

3) the delay in summoning the city's fire department;

4) the absence of concentrated and purposeful actions by the fire fighters in localizing the fire;

5) leaving the hatches of holds No 4 and 5 open after the fire broke out in hold No 2, leading to a fire in hold No 4 where the explosives were located;

6) the absence of oxyacetylene cutting equipment in good working order which did not permit cutting holes in the side of the damaged ship at the required moment.

In addition, the actions of the police who failed to warn ships and vessels in the harbor about the navigation catastrophe were adjudged incorrect. Finally, it was noted that the absence of signal devices for warning which could have been used to clear the piers of people who had gathered led to difficulties in organizing the fight against the disaster.

[pages 92-96]

5. Explosion of the Vessel "Grankam" and the military transport "High Flyer" (Texas Catastrophe)

Ammonium nitrate is widely used in military affairs, for example, as part of high explosives in the group of ammonium-nitric HE (ammonites). Ammonites appeared for the first time in the 1860's-1870's. At first, they were employed almost exclusively in peaceful technology as safety explosives suitable for work under underground conditions, for example, in coal mines. During World War I ammonites received extremely wide distribution and were used to fill ammunition, especially in the field artillery and aviation. Mixtures of ammonium nitrate with various nitro coumpunds, primarily with TNT, found employment for these purposes first of all. As a rule, in their explosive effect ammonites are somewhat weaker than TNT, except for ammonal which is not inferior to TNT in its overall explosive effect. Thus, ammonium nitrate has a certain explosive potential which has been widely known in the world since the last century. But, isn't it strange, at least two big catastrophes were necessary in our century in order to become better "acquainted" with the explosive properties of ammonium nitrate.

The first of them occurred on 21 September 1921 in Germany when more than 500 people were killed and more than 2,000 buildings were destroyed during a catastrophe at the Opau [as transliterated] plant. It was established that this catastrophe was caused by the following reasons.

To break up the rock-like mass of ammonium nitrate, about 4,500 tons of which had been formed in the factory's warehouses, it was decided to use dynamite, detonating it in small charges. In the course of these explosions, the entire mass of the ammonium nitrate was detonated and an explosion of tremendous power occurred which caused a great disaster for the local population.

When two vessels blew up in April 1947, as a result of which one of the biggest catastrophes of the century occurred, "the explosive possibilities" of ammonium nitrate were conclusively cleared up. We are speaking of the catastrophe which occurred in the port of Texas City, Texas, in which chemical and petroleum plants predominated. Its circumstances were the following.

On the morning of 16 April, the French vessel "Grankam" (1942, 7,176 tons) was at pier "0" in the northern slip opposite the chemical plant of the Monsanto Company while the American military transport "High Flyer" (1944, 6,214 tons) was moored in the main slip not far from it. Another American military transport, the "Wilson Kini" [as transliterated] (1944, 7,176 tons) stood alongside the "High Flyer." All three vessels were comparatively small and of American wartime construction.

Ammonium nitrate in 40-kilogram paper bags was being loaded on the "Grankam" which had already been in port for several days. About 2,300 tons of this substance had already been loaded on the vessel, of which 1,400 tons went into hold No 2 and 880 tons in hold No 4. Boxes with spare parts, peanuts, and several administrative cargoes were in the tweendecks of these holds. Since the engines were being overhauled, the vessel with without propulsion.

At 0800 hours the port longshoremen appeared to continue the loading operations in hold No 4 and, when the hatch covers had been removed, there were no traces of fire to be seen. Everything seemed to be normal. But 15 minutes later, smoke began to be noticed coming from the open space of the hold. The attempt was made immediately to extinguish the fire using fire extinguishers and canisters of drinking water but the fire and smoke became so intense that the longshoremen and crew were forced to leave the hold. The hose from the fire main was prepared for action but the first mate did not permit its use for fear of damaging the cargo. Instead of this, he ordered closing the hatch with ribbands and feeding steam into the hold to extinguish the fire. This continued for several minutes because the hatch covers were torn away and the flame and smoke began to emerge from the hold even more intensely. Finally, the city fire department was summoned; it soon arrived at the site of the accident. The crew left the damaged vessel just before the arrival of the firemen. The crew members took off for the quay and joined the crowd of observers. The firemen were unable to develop any actions before the "Grankam" blew up and was completely demolished. This happened at 0912 hours, almost an hour after the start of the fire.

The entire fire crew, ship's crew, and the observers were killed instantaneously while burning fragments caused fires in many places in the port. Buildings on a large part of the port's territory were destroyed or heavily damaged. More than 400 people were killed. A large tidal wave flooded the port. The "High Flyer" which was torn away from the mooring lines with great force struck the "Wilson Kini" and both ships were pressed against one another. A barge 150 meters in length which was located 100 meters from the shore was thrown up on the shore.

The Monsanto chemical plant received the greatest damage. Its buildings were destroyed and caught fire one after the other. Many oil and gasoline tanks caught fire. Access to many piers was closed by fragments or fires. The port's water mains were put out of operation. Many firemen stopped working and fire departments from other cities, for example, Houston which is located 50 miles from Texas City, began to arrive to replace them. Troop units also arrived to help. Two tugs which had arrived from Galveston to help (seven miles from the site of the catastrophe) could not make their way through to the harbor because of the dense smoke and fragments.

Meanwhile, the hatch covers on the "High Flyer" flew off, exposing its cargo consisting of ammonium nitrate and sulfur. In this regard, 2,000 tons of sulfur were contained in holds No 2 and 4 while 300 tons of ammonium nitrate were in hold No 3. The sulfur in a warehouse on the shore caught fire and columns of suffocating smoke poured out. Attempts were made to tow both transports--the "High Flyer" and the "Wilson Kini"--out of the harbor but the ships were stuck together so strongly that there was no possibility of separating them. They began to move them out together. Midnight arrived. The crews received the order to abandon the ships since it was extremely dangerous to remain on them. And actually, after a short interval of time the "High Flyer" blew up. This was at 0110 hours on 17 April. The exploding transport was instantaneously destroyed. The "Wilson Kini' was also destroyed. The second explosion was the source of additional damage on the shore. The number of fires increased. Even buildings of reinforced concrete were damaged.

The governor of Texas declared a state of emergency in the city. Joint actions of the police and rescue teams continued and the fires were controlled only on 18 April.

According to official data, the number of killed reached 468 while more than 100 disappeared and about 3,000 were injured. Many were left without shelter and food. There were more than 15,000 such people.

The material loss from this catastrophe was estimated at 67 million dollars, approximately twice that in the Halifax catastrophe.

The following basic lessons were learned from the catastrophe in Texas City:

1) ammonium nitrate which is stored in the hold of a vessel in bulk possesses tremendous explosive potential and packaging it in paper bags also presents a certain danger. Consequently, it is recommended that this substance be loaded and transported on vessels in metal drums and wooden barrels; in this case, in the event of damage when loading a drum containing ammonium nitrate it should be removed from the ship immediately;

2) ammonium nitrate must be stored absolutely insulated from any oxidizing effect of inflammable or explosive material, this requirement pertaining to the entire hold space including the tweendeck;

3) ammonium nitrate should be stored at a safe distance from steam conduits and electric cables

4) it is recommended that ammonium nitrate not be transported on flush-deck vessels since conditions are created on them which are more favorable for the shifting of fire from one hold to another;

5) delay in summoning the fire brigade may prove fatal for a burning vessel; therefore, such a summons should be made immediately in the case of any fire which breaks out on a ship in port;

6) when ammonium nitrate is burning, in no case should the hold be closed and, to extinguish the fire under these conditions neither steam, carbon dioxide, nor foam should be used; this is connected with the oxidizing ability of ammonium nitrate which leads to intensification of the fire and the possibility of explosion;

7) to extinguish a fire of ammonium nitrate, it is necessary to employ water alone and in large quantity (looking out for the stability of the ship). Therefore, water hoses on ships with ammonium nitrate should always be ready for use.

The correctness of the conclusions which were drawn was confirmed in the same year by the experience of one more catastrophe.

On 28 July 1947, the Norwegian vessel "Ocean Liberty" (1943, 7,176 tons) which had taken on a mixed cargo including more than 3,300 tons of ammonium nitrate was in the port of Brest, France.

When a fire broke out on the vessel, despite the well-known "Texas lessons" steam was again used to extinguish it and the vessel exploded and sank approximately five hours after the first fire appeared. In this case, 21 were killed and more than 100 were injured. Fires broke out in the city. The material loss was estimated at 2 million dollars. Losses could have been considerably greater if the vessel had not been led out of the harbor where there were a great number of ships and vessels.

[Pages 97, 105-145]

§6. Analysis of the Effects of Fires and Explosions on Ships and Fire-fighting Measures

1. Statistical Analysis

The analysis was accomplished on the basis of an examination of 193 instances of fires and explosions whose distribution by classes of ships and types of damage is presented in Table 2 [not reproduced]. Of 137 instances of fires without fatal consequences, 82 are contained in the book. A list of 56 instances of fires and explosions on ships with a fatal outcome is presented in Appendix 1 [not reproduced], 13 of which are described in this chapter.

In view of the specific nature of aircraft carriers as regards the effect of fires and explosions on them, they are analyzed separately. Then follow a general analysis for ships of other classes and a comparative analysis of carrier- and non-carrier ships. An analysis of 45 cases of damaged carriers provided the following results.

The main reasons for fires and explosions are errors in the actions of personnel (24 percent) and spontaneous combustion of fuel and the explosion of its vapors (19 percent); a noticeable portion is occupied by explosions of hydraulic systems (12 percent); then come malfunctions of electrical equipment (7 percent) and mechanical damage, electric welding, and the heating of steam conduits (3 percent each). Unknown causes account for 29 percent.

Among the reasons which we know, a significant role is played by reasons of a structural nature.

For degree of damage to ships, heavy and medium damage entailing expenditures calculated in many millions of dollars occupy the main place (about 60 percent) while insignificant damage provides approximately 30 percent. The amount of damage is not indicated in 10 percent of the cases.

As a rule, fires and explosions on carriers lead to large human sacrifices. The greatest share (35 percent) here consists of from 10 to several dozen killed and injured; then comes the number of victims up to 10 (31 percent) and more than 100 killed and injured also provides an impressive figure (7 percent). Only seven percent of those recorded are without victims and 20 percent are unknown.

Analysis of the aftereffects from fires and explosions shows that in not one accident, and what what is more, in not one catastrophe did carriers remain in action, that is, they could not continue the normal accomplishment of their missions. Ships were put out of action for several days in 42 percent of the cases, for several weeks in 37 percent, and for several months in 16 percent. Unknown cases comprised five percent. Thus, instances where carriers were put out of action for a considerable period--from several weeks to several months--comprise more than half the cases. Here, it should be considered that together with the carriers the screening and auxiliary ships which took part in extinguishing fires and eliminating their aftereffects, in towing the carriers to bases, and other types of support often stopped the accomplishment of their direct functions.

On the whole, for material loss, victims, and overall aftereffects fires and explosions inflicted extremely perceptible losses on carriers even though they were not lost in this case. Catastrophes on the carriers "Constellation" (1960), "Oriskany" (1966), "Forrestal" (1967), and "Enterprise" (1969) led to the greatest human and material losses and to significant aftereffects. It was these catastrophes which were points of departure in the development of recommendations for increasing the fire safety of American carriers in the 1960's.

According to "age" of the damaged carriers, the "leading" position (58 percent) is occupied by ships with a period of service of from 1 to 10 years while a considerably smaller share (33 percent) consists of ships with a period of service from 11 to 20 years. More than 20 years of service provide five percent of the cases and during construction--four percent. This means that fires and explosions occur on carriers of virtually any periods of service. This is explained, evidently, not only by the nature of the accidents and catastrophes on these ships, but also by the fact that structural fire-prevention measures on carriers are introduced both during the construction of new ships and in the course of their modernization to which they are subjected rather often. Therefore, new ships, despite the improvement in their equipment, are not evidently and favorably distinguished from their predecessors. Furthermore, it is namely on new ships that accidents and catastrophes lead to extremely serious consequences as a result of the sometimes unsuccessful selection of people ("Forrestal,"1967).

Of certain interest are the situations under which fires and explosions break out. Analysis shows that they are connected most of all with work inside the ship (62 percent); then follow accidents during the landing (19 percent) and takeoff (14 percent) of airplanes and unknown cases--5 percent. Perhaps, these figures can be corrected "in favor" of takeoff-landing operations since the press, especially the U.S. Navy, often publishes data on a considerable number of flying accidents in American naval aviation. But regardless of this, it can be concluded that the possibility for the outbreak of fires and explosions on carriers does not have to be linked with stress situations. Extremely often, fires break out as a result of haste in accomplishing the urgent missions of the command (in particular, in preparing for combat operations) without consideration of the actual situation on the ships, especially the state of training of the personnel for the accomplishment of these missions.

From the cases which we have examined, it follows that fires on aircraft carriers are accompanied most often (43 percent) by explosions, either preceding them or being a consequence of them. Fires alone (without explosions) were recorded in 40 percent of the cases and explosions alone (without fires)--in 17 percent of the cases. Thus, about two-thirds of the accidents on carriers are connected with explosions whichwere caused by the large concentration of ammunition and aviation fuel on them.

Fires break out most often (44 percent) on the flight and hangar decks, in places where the aircraft are refueled and armed with various ammunition. Twenty-one percent is the share of other decks and service compartments, 21 percent also in the engine and boiler room, and 2 percent in the fuel tanks. The place where fires break out was not established in 12 percent of the cases.

In the overwhelming number of cases (72 percent), fires and explosions occur when the carriers are at sea which, unquestionably, is connected with the intensity of their use. Next come fires when the ships are anchored in their bases (16 percent) and at the yards (12 percent) in the course of building and overhauling the ships.

The duration of fires was: up to 4 hours--40 percent, up to 10 hours--7 percent, and up to a day--2.5 percent. In individual cases, fires lasted up to several days ("Forrestal," 1967--2.5 percent). We were unable to establish the duration of the fires in 48 percent of the cases. Here, for the most part (43 percent) the fires were put out with the involvement of the men and equipment of other ships or bases. Fires could be put out by the forces of the damaged ships alone in 37 percent of the cases. Unknown cases numbered 20 percent. All these data tell of the serious nature of the fires which occurred on carriers.

In conclusion, it should be noted that most of the accidents connected with fires and explosions on carriers belong to the first of the decades examined (1950's--43 percent) while somewhat fewer cases (39 percent) belong to the following decade. The first decade of the 1970's provides a figure of 18 percent. Thus, it can be said that no obvious reduction in the intensity of accidents and catastrophes on carriers is observed as regards time.

The 92 cases of damage from fires and explosions on non-carrier ships which we examined showed the following in the analysis.

One of the basic reasons for accidents (23 percent) is the ignition of fuel and the explosion of its vapors; next come explosions of ammunition (14 percent) and steam boilers and steam conduits (10 percent). Short circuits and defects in electrical equipment in general also provide 10 percent of the accidental emergencies; the same portion is made up of incorrect actions by the personnel and carelessness in handling fire. Such causes of fires as heated surfaces of mechanisms and pipes (5 percent) and fires from adjacent burning ships (2 percent) were noted. The causes of fires were unknown in 26 percent of the cases.

Fire emergencies on non-carrier ships, as a rule, cause significant (47 percent) and average (45 percent) damage to ships while damage of an insignificant nature is noted in only 8 percent of the cases. In accordance with this, fires and explosions cause extremely serious aftereffects. As a result of the accidents, ships were put out of action for several weeks (54 percent) and several months (13 percent). In individual cases, being out of action lasted for more than a year (2 percent). Thus, ships were out of action for a long time in more than two-thirds of the cases. In the other accidents, the ships were out of action for several days (23 percent) or were repaired by the efforts of the personnel (6 percent). Unknown cases comprise two percent.

Fires and explosions on non-carrier ships lead to large human losses. Thus, several dozen people perished in 7 percent of the cases, up to 10 in 33 percent, and various numbers were injured in 5 percent of the cases. Forty percent of the fires were without victims and 15 percent were unknown. Relatively large losses result from the explosions of turrets of the major caliber on gun-firing ships (the battleship "Mississippi"--1924, the cruiser "Devonshire" --1929, the cruiser "Saint Paul"--1952).

In a large number of cases (45 percent), the place where fires break out on ships is the engine and boiler rooms and their holds; then follow various service compartments (18 percent), artillery mounts, and open decks (10 percent). Fewer fires break out in fuel tanks and living quarters (from 1 to 3 percent). Unknown cases comprise 13 percent.

The extinguishing of fires by the efforts of the damaged ship alone was successful in a comparatively small number of cases (28 percent). There are many more accidents where other ships or the fire brigades of cities and plants were called upon to eliminate fires (43 percent). In 29 percent of the cases, there is no information on those who participated in eliminating fires on ships.

According to classes of ships, accidents with fires and explosions are distributed successively in the following manner: light ships--44 percent, armored ships--26 percent, small combatant ships and minesweepers--15 percent, auxiliary ships--12 percent, and landing ships--3 percent.

As regards the "age" of ships, a large portion of the fires (47 percent) broke out on ships with a period of service of up to 10 years, then (28 percent) on ships whose period of service is from 11 to 20 years and, finally, on ships with a period of service of more than 20 years--in 15 percent of the cases. On a number of ships, fires occurred while they were still under construction and test (10 percent).

Fires and explosions on non-carrier ships occurred more often (44 percent) on voyages at sea. A small number of fires are noted when the ships are in the bases (29 percent) and at the yards (21 percent). Unknown cases comprise six percent.

The fires which were examined broke out on the ships of 12 of the world's fleets. Among them (in order of decrease in the relative number of cases): Germany* (41 percent), United States (18 percent), Great Britain (16 percent), France (12 percent), Japan (4 percent), Italy and Roumania (2 percent each), and other countries--1 percent each.

A comparison of the circumstances of accidents on carriers and non-carrier ships may be of some interest.

The reasons for fires and explosions on carriers were most often errors in actions of personnel, and on non-carrier ships--explosions of ammunition in artillery mounts, the ignition of fuel, and explosions of its vapors.

In accordance with the degree of damage to ships as a result of fires and explosions on non-carrier ships, considerably more heavy and medium damage is distinguished in comparison with similar damage on carriers (92 percent to 60 percent) and, accordingly, there is substantially more insignificant damage

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* Here we have in mind Germany prior to its division into two parts. The FRG is included among other countries.

on carriers than on non-carrier ships. This is completely understandable since the carrier is a significantly more survivable ship in comparison with light and unarmored ships of various classes which comprise the majority among the damaged ships considered.

Up to 10 victims are encountered in an almost equal ratio on ships of both groups (about one-third of the oases), with the number of cases of killed on the order of several dozen men on carriers considerably more (35 and 7 percent). Accidents and catastrophes with more than 100 men killed are encountered only on carriers. There are considerably fewer fires in which there are no victims or where the victims are few on aircraft carriers in comparison with non-carrier ships. This is fully explainable if we consider that with big fires and explosions for which a large number of victims is typical, the carrier will withstand them where a light ship will be lost. And this is also connected with the relatively great survivability of the carrier in comparison with non-carrier unarmored ships.

A comparison of the aftereffects from fires for the two groups of ships shows that non-carrier ships go out of action for a long time more often than carriers (67 and 53 percent). This is the direct consequence of the degree of their damageability; for a short period, on the contrary, a smaller percentage belongs to non-carrier ships.

The "age" of the ships does not provide substantial differences between ships of both groups. Thus, for example, damaged ships with a period of service of up to 10 years are encountered in both groups in a rather large number of cases (about half), differing in the somewhat larger direction for carriers and in a lesser direction for other ships. The relative number of damaged cases with the ships' period of service of 11 to 20 years is also close in both groups of ships and fluctuates with limits of 1/3. The difference becomes noticeable on ships with a period of service of more than 20 years. Here, there are substantially more accidents among non-carrier ships, which is explained by the ships' periods of service. Fires during the construction and testing of ships occurred more often on non-carrier ships.

A comparison of ships locations during accidents and catastrophes is interesting. While fires and explosions occurred on carriers more often at sea and considerably more rarely in bases and yards (correlation--72 and 28 percent), on non-carrier ships this correlation contains almost equal data and is even smaller for sea (44 and 50 percent). Perhaps, this is the result of the more intensive use of carriers in comparison with ships of other classes.

The analysis of the loss of ships from fires and explosions differs from the analysis of their damage without disastrous consequences. While a certain statistical sample in which, naturally, all cases of fires and explosion which are available could not find reflection was used for the analysis of damage, all cases of the loss of ships as a result of fires and explosions which are known to us were used in the analysis of disastrous cases. Furthermore, for the analysis of disastrous cases it was found expedient to expand the time range of the study somewhat and cases of the loss of ships were taken which occurred from the start of the century up to the present. All this was done to obtain the most general conclusions possible from the statistical analysis of cases of ship losses. At the same time, as was indicated above, the comparatively small number of cases of losses could be described in detail. The ships which survived provided more materials for details and they found reflection in the book. These special features were reflected somehow in the analysis which was performed.

The statistical processing of cases where ships were lost to fires and explosions led to the following results.

Among the ships which were lost, a considerable share (39 percent) is occupied by armored ships; then come auxiliary vessels (27 percent), light ships (18 percent), and a group of small combatant ships and mine sweepers (14 percent). During the last period, the loss of only one carrier was recorded (2 percent). The large share of the loss of armored ships can be explained only by the fact that the explosions of ammunition magazines often occurred on them. In these cases, the ships rarely remained afloat but were lost most often. Here, the loss of ships occurred so rapidly that no effective measures to save them could be undertaken. For example, some big ships were lost in 20-45 minutes ("Leonardo da Vince--1916, "Tsukuba" [as transliterated]--1917) and others in only 4-5 minutes ("Matsushima"--1908, "Kavachi" [as transliterated]--1918). The relatively high loss percentage of auxiliary ships is explained by the fact that that explosions of ammunition and explosives occurred rather often on them. It is paradoxical, but a fact, that only one carrier was lost to fires and explosions during such a long period of time (we recall--non-combat action). This was the British carrier "Desher" [as transliterated]. The explanation of this fact can be sought in the idea that, for a number of reasons, explosions of ammunition magazines did not occur on carriers as on other ships. During fires, as a result of their design features they went out of action most often but were not lost as, for example, light ships.

Of interest is the circumstance that the overwhelming majority of ships (86 percent) were lost in bases and only a small portion (12 percent) were lost at sea while unknown cases comprise 2 percent. This should only be explained by the fact that at bases vigilance on ships (especially as concerns fires) is considerably lower than at sea.

The main reason for the loss of ships is the explosions of ammunition magazines (41 percent); then follow internal explosions (20 percent) among which there may be explosions of ammunition or steam boilers and the explosions of steam boilers proper (11 percent). Thus, in three-fourths of the cases the loss of ships is connected with various explosions which occur on them. Other reasons such as a malfunction in electrical equipment, electric welding, the spontaneous combustion of fuel, mechanical damage, and fire on adjacent ships provide 3-5 percent each, comprising about 20 percent in sum, while unknown reasons comprise 8 percent.

Attention is attracted by the tremendous sacrifices which are the consequences of fires and explosions on ships with a disastrous outcome. Coming forth to the foreground here (34 percent) are cases of ship losses on which the victims numbered hundreds of prople. For example, on the Japanese battleship "Kavachi" more than 500 men were killed while 608 and 738 men were lost respectively on the British battleships "Bulwark" and "Vanguard." In 23 percent of the cases, the victims numbered dozens while in 12 percent they numbered up to 10 men or there were no victims at all. Unknown cases comprised 31 percent. Altogether, up to 6,000 men were lost on these ships. But some explosions of ships, primarily military transports, were sources of a colossal number of human victims on adjacent ships and vessels as well as on the shore. In four catastrophes alone (Halifax, Bombay, "Mount Hood," and Texas) 6,570 killed and missing were recorded, there were 15,500 injured and burned, and about 40,000 left without shelter (without Bombay).

The geography of the lost ships' countries embraces 16 fleets. Here, 23 percent belong to the United States, 16 percent to Great Britain, 14 percent to France, 9 percent each to Germany and Japan, 7 percent to Italy, 5 percent to Sweden, and 17 percent to the remaining countries.

In general, this is the statistical picture of fires and explosions on ships. Let us now examine some of the qualitative characteristics of the problem and, at the same time, those measures which are being undertaken or are contemplated in foreign fleets to increase the fire and explosion safety of ships.

2. Factors in the Fire and Explosion Danger of Ships and Fire-Fighting Measures

A qualitative analysis of accidents and catastrophes permits us to ascertain the basic factors of fire and explosion danger of ships and the nature of the effect of fires and explosions on ships of various classes as well as the behavior of ships and people in the presence of such effects.

On the basis of the analysis and study of a number of publications, it also became possible to determine several, perhaps the main, trends in the development of measures to increase the fire and explosion safety of ships in the navies of foreign states, especially of the United States and Great Britain.

It should be kept in mind that fires and explosions are extremely widespread types of accidents which occur on ships as a result of the effect of enemy ammunition on them as well as with non-combat effects. These accidents can be arbitrarily called "universal," in contrast to, let us say, the collisions of ships or their grounding--accidents which, as a rule, are not connected with combat effects. It is namely by considering the "universal" nature of fires and explosions that the problem of the fire and explosion safety of ships is solved with consideration of the experience of combat and daily service.

The experience of World War II showed [89] that the fire- and explosion danger of ships in foreign fleets is their weak point. This pertains especially to aircraft carriers: the damage to aircraft carriers in the period of the war (for all fleets) was connected with fires and explosions in approximately 30 percent of the cases. Fires broke out on carriers when they were hit with virtually any types of ammunition--aerial bombs, torpedoes, artillery shells, or "kamikaze" airplanes. The loss of almost all 11 U.S. carriers during the war was accompanied by fires and explosions. Fires and explosions on the flight decks and in the hangars also served as the main reason why the heavy American carriers "Franklin," "Saratoga," and "Ticonderoga" and a number of other ships which were hit by aerial bombs and "kamikaze" airplanes were put out of action (without disastrous consequences). Therefore, even in the course of the war measures were undertaken in the fleets of the United States, Great Britain, and Japan to strengthen the fire safety of carriers.

The acuteness of the problem grew substantially in the postwar years. The absolute and relative weight of aviation ammunition and aviation fuel (Fig. 19) [not reproduced]--these two main fire- and explosion-hazardous components on ships--increased several-fold on carriers. Postwar accidents and catastrophes on American carriers indicate that not only old and modernized carriers, but also the biggest newly constructed U.S. carriers proved to be insufficiently secured as regards fire-fighting capability even under the comparatively simple service conditions without the enemy's combat effects. The acuteness of the problem is intensifying with the ever-increasing dimensions and cost of these ships. Thus, for example, the total displacement of a contemporary nuclear carrier of the "Nimitz" type reaches almost 95,000 tons and its construction cost is 1 billion dollars (including the airplanes). The cost of maintaining carriers is also increasing continuously as a result of the constantly increasing complexity of their equipment and the growth in the size of the crew which comprises more than 6,000 men. A considerable increase in the cost of ships is caused by the natural striving to increase their safety and keep them in action under various emergency situations, especially with fires and explosions. Therefore, special attention is devoted to questions of ensuring the fire safety of carriers.

These questions also pertain to ships of other classes to one degree or another. In recent years, fire on a ship has been declared "enemy No 1" in the United States. That great significance is attached to this problem is shown by the numerous instances of its discussion in the press, at symposiums and conferences, and in various discussions. The flow of publications has intensified especially during the last 10-15 years in connection with events on U.S. carriers.

Various studies and tests which were conducted to clarify individual specific questions of "fire" subject matter, actual measures already adopted and being adopted on active ships, and the urgency in executing all orders in this field point indisputably to the serious significance which is attached to this problem.

The fire safety of ships is ensured by a complex which consists of three groups of measures--structural, organizational-technical, and the crew's actions in fighting fires. Measures of all three indicated groups are considered important for the full-fledged ensurance of ship fire safety. However, judging from data in the foreign press, main attention is being devoted to the group of construction measures which are called upon to provide a warning and the localizing of fires and explosions and to incorporate technical means for fighting fires.

In examining individual fire-hazardous factors and methods for fighting them, we will consider where possible measures of all three of the indicated groups.

/Fires in the engine and boiler rooms/. Experience shows that a rather frequent type of accident on ships of a number of classes consists of fires in the engine and boiler rooms.

Accidents for these reasons occurred and are occurring until recently on ships of various fleets and classes (the battle cruiser "Reknown"--1927, the destroyer "Anton Schmidt"--1940, the torpedo boat T1--1943, the heavy cruiser "Newport News"--1956, the carrier "Kitty Hawk"--1973). Work [26] points out that during the last three months of 1940 alone and on ships of the German navy alone there were 60 fires as a result of the spontaneous combustion of lubricating oil and liquid fuel. According to other data, there were several hundred fires in the engine and boiler rooms of battleships, cruisers, destroyers, and ships of other classes on German warships in the period of World War II.

Fires in engine rooms were the result of the ignition of lubricating oil (from the bearings of the main and auxiliary mechanisms) when it fell on the hot surfaces of turbines or conduits. To prevent this, it was recommended that the design of mechanisms be incorporated which would exclude the possibility that the oil from the bearings would leak through and spray, that heat insulation which does not permit oil to pass through be used, and that use be made of noncombustible protective coatings which would protect the surfaces from the spread of fire over them. Paints should possess low heat conductivity to ensure the slow rate of the fire's spread. Among the recommendations of an operating character it was pointed out that the personnel of engine rooms must systematically check and tighten the packing of the mechanisms' oil lines.

Accidents in the boiler rooms were more serious. Many accidents and catastrophes were noted whose causes were the explosions of steam boilers on ships. In the majority of cases (about two-thirds), such explosions led to the loss of the ships while in the other cases they only caused damage (sometimes serious) but they ships remained afloat here. Interestingly, among the nondisastrous instances of boiler explosions, of which six were recorded, half occurred in the 1920's and the other half in the 1970's. The guided missile destroyer "Goldsborough," the escort destroyer "Basilone" (both of the United States), and the landing ship, dock "Candido De Lasala" (Argentina) on which explosions of the steam boilers occurred (respectively in 1970, 1973, and 1974) were heavily damaged as a result of this although they remained afloat.

The reason for the explosion of a boiler is usually the overstraining of its walls, as a result of which their integrity is destroyed. This may be the result of excessive steam pressure in the boiler (when the safety valves or pressure gages fail), a lowering of the water level in it (because of the personnel's oversight), shortcomings in the design of the boiler (due to errors in calculations, low quality of materials, or defects in manufacture), and its incorrect servicing and maintenance. As is evident, there are both design as well as operational reasons. To avoid explosions in boilers, these points should be considered in the process of designing, manufacturing, testing, and operation of boilers on ships.

In boiler rooms, many fires were caused by the ignition of fuel oil. Here, "bilge fires" often occurred when water accumulated in the bilges and the remnants of oil floating on its surface ignited if they proved to be close to the hot sections of the boilers. To exclude such fires which, as a rule, occurred as a result of omissions by the personnel (infrequent checking and cleaning of the bilges), it was directed that the boiler room bilges be kept dry, checking their condition systematically. Furthermore, it was recommended that bilge-water oil purifiers be employed on the ships.

Some fires had as their source the burning of soot in the smokestacks. This occurred either due to the use of too greasy a mixture of boiler fuel or as a result of the infrequent and late cleaning of soot from the smoke uptakes. In these cases, it was sufficient for sparks to land on the soot which had accumulated to cause a fire. Such fires can be eliminated by conducting the systematic and thorough cleaning of the boiler smoke uptakes.

/Fires from the ignition of light types of fuel/. Considerably greater damage to ships is linked with the effect of fires and explosions on them which are caused by the ignition of light types of fuel.

Thus, for example, on torpedo boats and minesweepers where gasoline engines are employed, rather frequent fires and explosions occurred as a result of the gasoline's ignition and the explosion of its vapors. Frequently, the sources of such fires were leaks in the gasoline systems, because of which the gasoline spread and, landing on the hot surfaces of mechanisms and conduits, caught fire. These fires and explosions led to the ships' going out of action and, sometimes, to their loss (German torpedo boats and minesweepers). They were one of the basic reasons for the change to diesel engines in place of gasoline engines on small combatant ships and minesweepers.

"Gasoline" fires and explosions occurred on cruisers in the areas where gasoline tanks were located because the tanks, in particular, were left empty and were not refilled with water (the cruiser "Goritsiya" [as transliterated], 1959). Such accidents led to local damage on ships.

However, noted most often were fires and explosions connected with the combustion of aviation fuel on aircraft carriers which occurred under the most diverse conditions. A number of fires and explosions were connected with the leakage of fuel from defective fuel tanks and its ignition ("Indomitable,'

1953) while others were the result of the unsatisfactory condition of ships electrical equipment, especially the high-voltage network ("Ranger" and Randolph," 1959). Such explosions led to the damage of ships and human victims. Many accidents occurred on flight decks during unsuccessful takeoffs and landings of airplanes ("Essex," 1951 and 1959, "Oriskany," 1954, "Hancock," 1958). The fuel fire catastrophes on the "Forrestal" (1967) and "Enterprise" (1969), which also began from the flight decks, became sadly well-known. In the latter cases, the fires were accompanied by the explosions of bombs and rockets which intensified significantly the effect of their destructive action on the ships. Aviation fuel fires also occurred in the hangars during the refueling of the airplanes when preparing them for takeoff ("Wasp," 1955, "Oriskany," 1966). There were also fires when taking fuel on the carriers ("Franklin D. Roosevelt," 1966). A big fire on the carrier "Constellation" (1960) also had the combustion of fuel on one of the ship's decks as its source.

Many of the aviation fuel fires and explosions led to large-scale catastrophes which were discussed earlier. In a detailed study of the circumstances of the accidents and catastrophes connected with fires of this type, it was established that in the majority of cases they were the result of incorrect actions and omissions by the ship's personnel. But there also were reasons of a design nature and an insufficiency of fire-fighting means was especially noted.

The constant and considerable growth in aviation fuel supplies on carriers is causing alarm for their fire safety in the future, too, in the foreign fleets.

Aviation fuel which is less fire-hazardous than gasoline is now being used in the navies of the United States and other countries. Thus, the heavier aviation fuel mark JP-5 which has a flash point of 60°C is used on U.S. carriers instead of the gasoline with a flash point of 10°C which was formerly used.

For fire-prevention purposes, the storage of gasoline on carriers was accomplished in "saddle-shaped" tanks surrounded by cofferdams with an inert gas (Fig. 20) [not reproduced]. Here, the transportation of aviation gasoline by ship is accomplished only in double pipes with external filling with inert gas. This system was adopted, for example, on French and American carriers. The storage of fuel for jet engines is much simpler. In this case, the cofferdams are eliminated and the placement of the fuel in tanks protected by armor which was employed earlier is abolished. A schematic diagram of aviation fuel's placement on a carrier for jet engines is given in Figure 21 [not reproduced].

The frequency of fires on flight decks and in the hangars of carriers, the speed of a fire's spread through a ship, and the nature of its destructive action--all this dictated the urgent necessity to adopt imperative measures to reinforce the means for fighting fires on flight decks and in hangars. And, actually, such measures were adopted, especially in recent years. The future will show the practical effectiveness of these measures, but the scales of work accomplished and planned are such that, in all probability, they will correspond to the assigned task of increasing the fire safety of ships and, first and foremost, carriers.

Primary attention was devoted to the organizational formulation of the matter. And at the end of the 1960's the MTO [logistic support] of the U.S. Navy created a special group to coordinate all work on the development and use of new means to fight fires. Important scientific-research and industrial organizations as well as elements of the Navy were drawn into the accomplishment of the work. The direct development of fire-extinguishing substances was assigned to the Naval Research Laboratory (NRL) while supervision of questions concerning fire-fighting equipment was assigned to the command of the MTO. Development of new fire-extinguishing substances was considered to be one of the primary missions.

Such substances were developed for the needs of the U.S. Navy at the beginning of the 1960's. They included the foaming agent "light water" and the powder of potassium bicarbonate (purple K). It was also decided to use them on ships and, first of all, on carriers. "Light water" is a liquid mixture with a density of 1010 kilograms per cubic meter of a surface-active substance from synthetic carbon fluoride. This foaming agent, however, mixes well with fresh water as well as with sea water. The latter circumstance is extremely important for ships which have limited supplies of fresh water. It was established that foam with an expansion multiplicity factor of 7-11 can be generated from a six-percent solution of the mixture with the use of regular foam monitors. It has an important property--it spreads over the surface of burning fuel creating a thin but strong and cohesive (compactly coalesced) film which inhibits the emergence of combustible gases from the center of the fire, increasing considerably the flame-damping effect and making it stable.

Experiments have shown that the effectiveness of extinguishing burning fuel, (in particular of the JP-5-type) is two to five times higher with the new foaming agent ("light water") than with the former protein foam generator, and with potassium bicarbonate--three to four times greater than with the previously used powder on a sodium base and with carbon dioxide which is also widely used to extinguish fires on ships. Here, it was found that with the high effectiveness of these flame dampers they are also more economical since they require relatively less consumption of materials per unit of fire area than former substances.

The method of extinguishing burning fuel with these substances consists of the fact that first a flame-damping cloud is created from potassium bicarbonate to reduce the temperature and suppress the flame and then the center of the fire is covered with foam on a base of "light water."

These substances were tested comprehensively under range and ship conditions and, in 1968, were accepted in the U.S. Navy as the basic means for extinguishing fire on ships, primarily on aircraft carriers.

The self-propelled units of the airfield type (motor carts) with which carriers began to be equipped at the beginning of the 1960's (four per ship) had two fire-extinguishing substances (twinned agent unit)--"light water" and potassium carbonate. These carts had a "light water" feed of 189 liters per minute and a potassium carbonate feel of 2.26 kilograms per second. As was reported in the U.S. press, one charge of fire-extinguishing substances can ensure extinguishing a fire on an area of 230 square meters with a time of continuous operation of 1.5 minutes. Here, the reserve on the cart is 310 liters of water and foaming agent and 90 kilograms of potassium bicarbonate.

The use of two such carts to extinguish the fire on the carrier "Enterprise" showed that their feed is too low for such cases. In addition to this, the proximity of the carts to the point of the accident led to where bomb fragments destroyed the air-tightness of the cylinders with air and the containers with the fire-extinguishing substances, as a result of which they went out of operation. Therefore, it was decided to equip big carriers with mobile and fast fire engines (also of the airfield type) which possess a considerably greater feed in comparison with the carts. These were the MB-5 machines (Fig. 22) [not reproduced].

The foam monitor feed of the MB-5 engine is about 1,000 liters per minute of foam generating solution and up to 2.25 kilograms of powder. The engine has water tanks with a capacity of 1,510 liters, tanks for "light water" with a capacity of 113 liters, and a pump to feed the solution of "light water" to the foam monitor which is installed above the driver's cab. The engine is also equipped with a container to store the potassium bicarbonate powder, a sprayer, and a fire hose. The engine's total feed is approximately six times greater than the feed of the cart and the fire can be extinguished from a distance of about 30 meters, that is, from a safer distance. The "Enterprise," for example, is equipped with five such engines. They are considered as temporary from now on until the development of more improved fixed fire-fighting systems.

A system of water protection (SVZ, American designation NBC) has been adapted to extinguish fires on the flight deck. Its basic purpose is to wash away radioactive deposits when nuclear bursts occur. The possibility of using the SVZ to extinguish fires on flight decks was confirmed by special tests in which the conditions for the fire on the carrier "Enterprise" were reproduced. On these tests, with the use of a six-percent solution of "light water" as the fire-extinguishing substance, the extinguishing time was about two minutes. The test conditions were the following: the amount of burning spread JP-5 fuel--13,000 liters, burning area--864 square meters, wind velocity--30 knots, and time of free combustion--60 seconds.

The SVZ sprayers are installed on the flight deck by zones, the length of each of them being about 38 meters. A zone with an area of about 930 square meters is served by an independent SVZ main. Control by zones is accomplished remotely from control panels located in the pilot room and in the aircraft flight control post. The system can also be controlled from the ship's control post for takeoff and landing operations.

The sprinkler system for the hangars is controlled from fire stations located on the hangar deck. It is planned to put this system into operation automatically from fire-detection notification equipment.

At the same time, foam generators of the protein type were replaced by "light water" in a fixed ships system. This remotely controlled fire-extinguishing system on big carriers consists of 17 independent sections. Its basic elements (Fig. 23) [not reproduced] are: a tank with foam generator (with a capacity of 1,135 liters), a foam mixer-batcher (output for the foam-generating solution 3,785 liters per minute), remotely controlled fittings, pipelines, fire- and manual foam monitors, and fire hoses, drives, and signal equipment. The tank with foam generator, foam mixer, and remotely controlled fittings are located on the second deck. Control of the foam-extinguishing system is accomplished from the fire posts of the flight deck, hangar, and places where the foam mixers are installed.

In connection with the fact that the fixed foam-extinguishing system which was intended earlier to extinguish fires in hangars began to be employed to service the flight deck, too, and, in addition, it still had to support the SVZ and fire-extinguishing units in the MKO [engine and boiler rooms] as well as the compartments for electrical engineering and electronic equipment, the necessity arose to increase the number of foam generators on each independent section of the carrier. The former tank with the foam generator was replaced by another whose capacity was twice as great as the former tank. Supplying the fire-extinguishing system with sea water required an increase in the number of pumps for the water fire-extinguishing system and their total discharge which, in turn, led to an increase in the output of electric-power sources.

According to data in the American press, the feeding of foam to the flight deck or hangar is provided for 30 seconds from the moment that the fire signal is received. These are the technical capabilities of the system. But there are data which indicate that these capabilities cannot always be realized. Thus, for example, a general inspection which was conducted in the U.S. Navy in 1973-1974 showed that the fire-fighting equipment on ships, in particular on carriers, was in an unsatisfactory condition. On one of the carriers which underwent an inspection, for example, the sprinkler system on the hangar deck was not working. The "light water" foam generator on this same ship could not be used. Other shortcomings in the ship's foam-extinguishing system were also discovered which reduced its designed technical capabilities. Since this system is considered as one of the most important, especially in the complex of carrier fire-fighting equipment, great attention has been devoted to its technical condition on the ships.

Foam extinguishers which serve the engine and boiler rooms and the compartments for electrical engineering and electronic equipment are used on carriers (16 per ship) and on other (non-carrier) ships. Such units include: a fixed fire extinguisher with potassium carbonate powder, cylinders with compressed gas, paired hoses with sprayers, and a pipe to feed the "liquid water" solution from the foam mixers of the independent sections of the ship's fire-fighting system.

It is planned to employ the new fire-extinguishing substances on ships of all basic classes in the U.S. Navy.

Figures 24 and 24 [not reproduced] present types of fire-fighting monitors which are employed on the hangar decks of American carriers as well as in engine compartments and compartments for electrical engineering and electronic equipment.

During tests of the water protection system for extinguishing fires, the insufficient effectiveness of the sprayers in a strong wind was established. In the opinion of American specialists, a new type of sprayer which has been developed (Fig. 26) [not reproduced] ensures the uniform covering of flight deck sections with the foam-generating solution. U.S. carriers are outfitted with the new sprayers during repair.

In addition to the foam extinguishing systems which have been mentioned, a water fire extinguisher system which is used in virtually all ships compartments remains on the ships as formerly. And, as indicated above, the capacity of this system is continuously growing: for example, 18 fire pumps with a total feed of 100,000 liters per minute have been installed on the nuclear carrier "Nimitz" which, by the way, is approximately three times greater than the capacity of the water extinguishing system of "Essex"-type carriers. Ten pumps with a total feed of 34,000 liters per minute have been installed on carriers of the "Essex" type. The difference in the capacities of the foam extinguishers on these carriers, the correlation of which is 10:1, appears even more striking. While the total output of the foam extinguisher on "Essex"-type carriers is 450 liters per minute, it is 4,500 liters per minute on the "Nimitz." This correlation is explained not only by the difference in the size of the ships, but also by the considerably increased requirements for fire safety on the carriers.

The following list of technical fire-fighting equipment which is employed on large U.S. carriers has been developed up to now:

1) water-type fire extinguisher system--for all ship compartments and decks;

2) fixed foam-extinguishing system--for flight decks and hangar;

3) fixed foam-extinguishing units--for engine and boiler rooms and compartments for electrical engineering and electronic equipment;

4) water protection system with foam extinguishing--for flight decks and superstructures;

5) foam extinguishing sprinkler system--for hangars and individual sections of the main deck (in the area of the stern);

6) MB-5 fire engines and self-propelled carts with foam extinguishing--for flight and hangar decks.

Furthermore, all interior compartments of ships are equipped with powder fire extinguishers.

The systems which have been indicated are also employed on ships of other classes with different variations.

Along with the improvement of fire-fighting equipment, a number of measures for structural protection are being accomplished on flight decks and in the hangars of carriers. When preparing for takeoff, to protect the airplanes and personnel in the area of the catapult from the dangerous heat and dynamic effects of the gas jets from the jet engines of airplanes on the catapult a special device for their deflection is incorporated on the flight deck. The construction of the device, usually in the form of deflecting panels, must provide the reliable deflection of the jet flow in the required direction in accordance with the basic purpose and in such a way that it does not have a harmful effect on the tail assembly of the airplane being catapulted.

Fire-resistant screens (shutters) made of reinforced asbestos are used in hangars to localize the effect of fires and explosions. Under normal conditions, these screens are in the rolled-up condition beneath the hangar deckhead. When necessary, they can divide the hangar into a number of self-contained compartments, as a rule, into three, in 30 seconds.

Because considerable flooding of the hangar may occur with the operation of the sprinkling system, drainage holes are installed along its sides. Similar holes are also built on the flight deck.

/Ammunition explosions/. Let us now examine the nature of damage to ships as a result of the explosions of ammunition which occur on them (of course, not from the effects of combat) and the measures which are directed toward their prevention.

The experience of accidents and catastrophes shows that at least three types of explosions occur on ships. The first is the explosions of individual pieces of ammunition, the second--explosions of ammunition rooms, and the third--explosions of HE being transported on military transports.

Explosions of the first type occurred primarily in gun turrets and deck gun mounts (the battleship "Mississippi"--1924, the cruiser "Devonshire"--1929 and the cruiser "Saint Paul"--1952, the destroyers "Bak" [as transliterated] and "John Pierce"--both 1956, and the cruiser "Newport News"--1972).

Such explosions were usually connected with incorrect firing procedures or with carelessness in the conduct of fire, and with the poor maintenance of the gun systems, in particular the tubes. This question was examined in rather great detail in analyzing the case of the turret explosion on the battleship "Mississippi." The consequences of such individual explosions were damage to the ships and a certain number of human victims but, as a rule, the ships were not lost in this case and remained afloat. Explosions of this type also include the explosions of individual mines (the minelayer "Tokiva" [as transliterated]--1927) or depth bombs (the destroyer "Sepoy"--1930) and other ammunition. They did not lead to the loss of the ship, either.

Explosions of individual pieces of ammunition occurred on carriers when airplanes were landing on the ship. The carrier "Saratoga" (1964) can serve as an example. The carrier received heavy damage but the number of casualties was relatively small. This case did not entail such disastrous consequences as the explosions on the "Forrestal" and "Enterprise" since there was no crowding of airplanes in the landing zone, the number of explosions was small, and the centers of fire which broke out could be eliminated relatively quickly.

The source of an explosion of the second type may be the spontaneous combustion of powder in a magazine or the careless handling of powder and fire within the magazine or, finally, sabotage. Spontaneous combustion of powder may be the result of its failure to meet standards (for reasons of powder composition, defects in manufacture, or duration of storage) or violation of ammunition storage conditions, in particular, the rising of the temperature in the magazine above the allowable. In this case, the decomposition of the powder begins, leading to its ignition and then to an explosion.

Carelessness in handling powder may be manifested in the insufficient ventilation of the magazine, as a result of which the formation and accumulation of an explosive mixture may occur in it which is dangerous in regard to the ignition of the powder. The presence of an open fire in the magazine was the source of powder ignition and the explosion of the magazine many times. As is evident, there may be many reasons for the explosion of an ammunition room and they actually occurred. The reasons for this are frequently of an operational nature but, at the same time, they are linked with the quality of the ammunition used and also depend on the construction of the magazines, their fire-fighting equipment, and its condition.

In practice, explosions occur not only in individual magazines but also in groups of magazines (the iron-clad cruiser "Natel"--1915, the battleship "Tsukuba" [as transliterated]--1917) and even of all the ship's magazines (the battleship "Leonardo da Vinci"--1916, the battleship "Vanguard"--1917).

It should be mentioned that it is evident from the materials at our disposal that such explosions occurred in all the main fleets of the world except the German fleet. Is it the result of "keeping a military secret" or the result of a more "careful" and thoughtful attitude toward these questions in the former German Navy? Perhaps, both are observed here. But if we consider the behavior of German ships under combat conditions, it can be assumed with great confidence that the German fleet worked with powder more seriously because even with combat effects on ships, the powder charges rarely exploded but burned more often without exploding. Let us recall the case of the German battle cruiser "Doerflinger" at the Battle of Jutland. Fires broke out on this ship as a result of hits with heavy shells (381-mm) in turrets Nos 3 and 4, and the ignition of the powder in the powder magazines occurred. The powder burned, but it did not explode, saving the ship since there were no explosions of the magazines. In the British fleet, on the contrary, the powder magazines often exploded, leading to the loss of the ships. Here, a large quantity of cordite was quickly ignited and, after it burned for a short time, the magazine exploded. Lost in this manner in the same Battle of

Jutland were the British battle cruisers "Indefatigable," "Queen Mary," and "Invincible." The British battle cruiser "Hood" was lost in this manner in World War II.

The overwhelming majority of ammunition-room explosions led to the destruction of the ship and its loss and were accompanied by large human losses. Therefore, despite the fact that in recent years explosions of ammunition rooms are observed rather rarely, special attention has been paid to the prevention of such explosions. This will be even more understandable if we consider that on many contemporary ships there is ammunition with which the explosion of the room may load not only to the destruction of the ship itself but also to innumerable calamities and losses around the ship and at a great distance from it.

Just what measures can be adopted to prevent such explosions? First of all, of course, they are measures of a structural nature since it is they which are directed toward preventing the possibility of an explosion.

We will begin with the fact that on large ships the attempt is made to locate the magazines in the most protected places possible. For example, on the contemporary carrier the ammunition rooms are located in the cidatel, in its bow and stern sections, beneath all armored decks, and behind the underwater protection belt (Fig. 27) [not reproduced]. The placement of the magazines as far as possible from one another reduces the probability of detonation of all the ship's ammunition as a whole. Other generally accepted measures on ships are: the storage of pyrotechnic material in places where their chance combustion will not cause damage to the ship's vital parts; the presence of automatic alarm systems concerning the increase of temperature in the magazines and the detection of ignition in them; the employment of automatic sprinkling systems (sprinklers), the actuating of which is based on various physical principles (temperature, pressure, light, and smoke).

In recent years, special attention is being devoted to the structural fire-prevention protection of missile magazines. Foreign specialists believe that the probability of an outbreak of fires and explosions in them is higher than in gun magazines. This is because of the possibility of instances of closure of the electric circuit which connects the on-board equipment with the pre-launch checkout instruments or of the landing of fragments or small-caliber shells in the booster or sustainer engines on light ships. To avoid the chain ignition of all ammunition in the missile magazine, the U.S. Navy has begun to employ a special automatic system for the forced injection of water into the nozzle of the PRD [powder rocket engine] in the ZURO [antiaircraft guided missile] magazines of ships [45].

On range tests of "Terrier"-type antiaircraft missiles it was established that the ignition of one of the PRD's causes the ignition of adjacent missiles and, eventually, of all ammunition in the magazine. In this case, extremely high temperatures and pressures of the powder gases are developed in the course of the engines' burning. Referring to the results of the tests which were conducted, U.S. specialists assert that when using a system of forced water injection the booster engine which has been ignited from a chance short circuit may, in the majority of cases, be extinguished before the combustion encompasses a considerable number of tubular propellent grains with which the rocket engines are started. In this regard, an automatic device can ensure the actuating in several milliseconds.

When a rocket engine is ignited by a fragment which hits, the system's effectiveness is reduced and the time for actuating the automatic devices is increased to several seconds. However, the injection of water into the combustion chamber decreases the intensity of combustion in this case, too, to a degree with which the ignition of adjacent missiles is prevented.

The injection system is a component part of the ship's main fire line and communicates with it through a check valve. A greater pressure is maintained in it than in the fire main. This is attained with the aid of a pneumatic pressure tank--a water accumulator which is connected with a compressed air unit.

The pneumatic pressure tank and all piping of the system are filled with fresh water under normal conditions. The magazine is serviced by an annular pipeline which branches off from the system. This line has nozzles to inject water into the PRD nozzle. Pressure sensors and special fast-opening stop valves are installed on the injection nozzles. The number of nozzles corresponds to the number of missiles in the magazine which are stored on a special conveyer. This conveyer provides for the feed of the projectiles to the lift to a position for loading the launcher. When the conveyer moves, the missiles occupy certain oriented positions in turn in which an injecting nozzle is located beneath the nozzle of the booster engine of each missile. The pneumatic pressure tank maintains a constant pressure in the system after the nozzles are opened until the moment when the fire pumps are put into action. The pumps are turned on automatically with the start of operation of one of the injection nozzles and maintains the assigned pressure in the main fire line, beginning from the moment when the pressure in the pneumatic pressure tank drops to a certain value (in existing systems, for example, about 4 kg/cm^2).

On the whole, American specialists consider this system to be sufficiently effective and employ it in ZURO magazines on aircraft carriers, missile carriers, and other surface ships.

The schematic diagram of a fire-fighting system for the ZURO of the U.S. missile cruiser "Canberra" is presented in Figure 28 [not reproduced].

Over a period of 60 years, a number of technical devices intended for the protection of missile and artillery magazines against explosions were patented in the United States.

Thus, for example, the design for an impenetrable steel shutter as a means for protection against flame in missile launchers was patented in 1962. It is expected that the shutter will be installed at the junction of the magazine for expendable ammunition and the prelaunch station or the launcher.

Two years later, the U.S. Navy was issued a patent for a sprayer head having a new design for an automatically operating sprinkler system and artillery magazines. According to the authors' statement, its employment will ensure obtaining a powerful flame-damping screen in the shortest time which reliably prevents the explosion of ammunition in the magazine. A patent for an improved design of a ship's launcher for the launching of antiaircraft missiles was issued to the U.S. Navy in 1966. The design incorporates the employment of special fire-fighting equipment as well as means for localizing a fire and withdrawing the red-hot gas jet in case one of the missiles located in the drum is ignited. The means employed in the device which has been patented, according to the authors' thoughts, will permit the automatic isolation of the burning compartment from the other compartments in which the missiles are stored. The elimination of a fire which has broken out and the removal of the gases which are released outside the ship are envisaged with the use of this equipment.

Searches for new means and methods to protect missile magazines from explosions have been continuing recently. Thus, in 1972 the description of a device intended to provide the explosion safety of rocket engines stored in magazines located in the depth of the ship was published [47]. One of the versions of this device which was tested on the engines of the "Sparrow" missile is shown in Figure 29 [not reproduced]. This device envisages the automatic bursting of the rocket engine housing with its chance ignition which, with the equalization of pressure in the engine's combustion chamber and in the magazine, should exclude the explosion of the magazine.

A new system for the storage and feeding of aviation ammunition [9] with the maximum use of mechanization and automation of the control and monitoring of its flow which was installed at the end of the 1960's on the carrier "John F. Kennedy" and adopted for other U.S. aircraft carriers has been called upon to provide not only the acceleration of the processes for the reception and feeding of ammunition, but also great reliability and safety in operation which reduces the possibility of accidents to a minimum.

In analyzing the catastrophes on the "Forrestal" and the "Enterprise," it was established that soon after the outbreak of the fire the bombs which put the crew members who were fighting the fire out of action began to explode. In this connection, a special fireproof coating which protects aerial bombs from explosions during fire was developed and tested in the United States. According to data of the Americans [13], this coating increases the explosion time of the bombs to five minutes. The coating was tested for aerial bombs weighing 113 kilograms.

As regards preventive measures of an operational nature, here the main role is played by the ships personnel's firm and specific knowledge of the ammunition's physical-chemical properties and the degree of its danger as well of the rules for its reception, storage, and feeding and knowledge of the design of magazines and technical systems which provide their fire protection. Great significance is had by firm procedure on the ship and strict discipline as regards the observance of rules and instructions on handling ammunition on a ship as well as access of only a certain group of individuals established by the ship's command to the magazine.

Explosions of the third type arise most often on military transports. As regards their physical nature, they are connected with the detonation of explosives which are being transported by transports, frequently in extremely large quantities which reach several thousand tons of TNT equivalent (the "Montblanc," "Mount Hood"). Consequently, the destructive effect of such explosions is equal to the destructive effect of a small-yield atomic bomb with the only difference that in this case only the mechanical effect of the explosion occurs without the other casualty-producing factors which are inherent in a nuclear explosion.

Most often, the source of such explosions is the ignition of inflammable substances which are often transported together with the high explosives. In this case, the "incompatability" and danger of such shipments, the rules of the "International Convention on the Protection of Human Life at Sea," and the requirements of military and naval organs in accordance with whose orders these shipments are accomplished are often ignored. For example, the source of the explosion in Bombay was a burning cigarette from which cotton caught fire and which led to the explosion of a tremendous mass of HE which was being transported together with the cotton. Explosions of this type led not only to the complete destruction of their ship. Since they occurred in ports, their consequence was the destruction or heavy damage to the ships and vessels located there and to the port and shore structures in general which suffered from the burst shock wave, fragments of ships, their equipment, and heavy cargoes which disintegrated, and from the fire with the formation of large conflagrations which, as a rule accompany these explosions. Such explosions always had large human and material losses as their consequences. The number of victims, with consideration of the people who were left without shelter, reached several thousand people and, sometimes, tens of thousands.

It should be said that in all the cases of explosions on military transports which we examined, fires began as a result of neglect by the ships' personnel. The development of the fire and the initiation of the explosion were connected with the low level of training of the ships crews who did not know the basic properties of the combustible and dangerously explosive materials and did not have even elementary notions of the possible consequences to which these fires and explosions might lead. No small adverse role was played by the irresponsibility of the damaged ships' command personnel who sometimes abandoned the burning ships at their most dangerous moment ("Montblanc") and the indecisiveness of their actions and the incorrectness of the decisions which were made in fighting fires, especially at the initial stage of their development (Bombay), which led to the spread of the fires and, finally, to catastrophes and national calamities, not to mention the purely military loss to the warring side. The insufficiency of port support and the lack of clarity in actions by the military organs in these cases were also factors which contributed to the possibility of outbreak of fires and explosions and their development (Halifax, Bombay).

There were also shortcomings of a structural nature. They consisted of the fact that a shortage of technical equipment to fight fires was felt on a number of ships and, in some cases, such equipment was extremely deficient.

As becomes apparent from the lessons which were drawn on the basis of a review of the circumstances surrounding the catastrophes which were the consequence of powerful explosions on military transports, the prevention of such explosions or, at least, a reduction in the probability of their outbreak may be attained through the elimination of shortcomings in organizational and technical support which occurred on the part of the command personnel of ships and vessels, military and naval organs, and port authorities. Crews having special training should be selected on ships and vessels which transport explosives. Finally, ships and vessels intended for the shipment of HE should be equipped with the appropriate fire-fighting equipment. Here, both the rules of the "International Convention on the Protection of Human Life at Sea" and the requirements of the military and naval organs of states which are interested in various shipments of HE should be considered.

/Explosions of high-pressure systems/. One of the varieties of accidents which occurred on U.S. aircraft carriers consisted of explosions of hydraulic systems. Such explosions on the carriers "Bennington" and "Leyte" in the catapult hydraulic systems were accompanied by many human casualties. Explosions of hydraulic systems were also noted on surface ships of other classes and on submarines.

To explain the reasons for such explosions, broad experimental studies were organized in which various scientific and industrial organizations and organs of the Defense Department were involved.

The studies showed that the basic reason for explosions was a sudden increase in air temperature in dead-end sections of pipes as a result of its instantaneous adiabatic compression. In this case, the flame which breaks out at the end of the pipe is able to spread over the oil film which is present on the wall along the pipes of the system's remaining portion. It was established experimentally that the flash point of the pressure fluid in such systems may prove to be dangerously low with an increase in pressure. The graph in Figure 30 [not reproduced] shows the change in the value of the temperature for spontaneous combustion of the pressure fluid for one of the marks of those which are common on U.S. ships depending on pressure. It follows from the graph that the temperature at which the combustion of this fluid occurs drops from 350 to 180°C with an increase in pressure from 1 to 210 kg/cm^2 (the operating range of the temperatures and pressures of the most common types of air compressors on ships of the U.S. Navy).

But the studies were not only to explain the reasons for explosions; it was also necessary to find ways to eliminate them in the future. This task was accomplished by a comparative study of the characteristics of pressure fluids of various types--the path which leads closest to the goal. But unexpected and rather significant difficulties arose in the accomplishment of the task.

It turned out that the entire matter contradicted the various requirements for these fluids and it was difficult to find a pressure fluid which would meet simultaneously such requirements as high fire resistance, sufficient lubricating ability, hydrolytic stability, non-toxicity, anticorrosiveness, and durability in operation. For example, a fluid on a base of aqueous glycol, possessing satisfactory fire resistance, demonstrates low lubricating ability under conditions of heavy loads while some metals which are widely used in hydraulic systems corrode in these fluids. The same "incompatability" was demonstrated by phosphate esters, oil emulsions, and other fluids. Publications available on this subject [10, 16, 55] show that despite many years of study, no unambiguous and reliable solution of the problem had been found up to recent times.

At the end of the 1960's, explosions of high-pressure nitrogen systems (210 kg/cm^2) began to occur on U.S. carriers. Four such explosions were noted on three carriers. One of them, which occurred in the compressor chamber, led to the serious injury of three men and to serious damage to the hull and mechanisms. Here, the explosions occurred at the exit of the nitrogen from the nitrogen compressor and they had a rather directional nature.

Laboratory studies showed [27] that the reason for these explosions, obviously, was the increased oxygen content (above 3 percent) in the nitrogen which was caused by a malfunction in the oxygen analyzer and the landing of oil from the compressor cylinder lubrication system in the nitrogen.

It was recommanded that the condition of the oxygen analyzer be checked more often (several times per day) to prevent such explosions. Although this requirement is written in the instruction, it was not carried out by the servicing personnel. The remaining requirements are similar to those which are imposed on other high-pressure systems to ensure the safety of their operation.

/Other types of fires and explosions/. Short circuits and the malfunctioning of electrical equipment in ships in general were the reasons for a number of accidents, and even catastrophes.

There were several instances of the loss of ships for these reasons. True, the ships had a small displacement (patrol boats, torpedo boats, and minesweepers). But there was a rather large amount of damage to ships for these reasons. We have already mentioned the cases of damage to the U.S. carriers "Ranger" and "Randolph" which occurred from the malfunctioning of the high-voltage system on the ships, as a result of which fires and explosions broke out on them and they went out of operation. Similar accidents also occurred on many other ships, among which were the German destroyer Z23 (1942 and 1943), the heavy U.S. cruiser "Newport News" (1956), the British carrier "Hermes" (1963), and a number of others.

Fires and explosions for these reasons led to damage which entailed putting the ships out of action for various periods of time. The majority of electrical equipment malfunctions had an operational nature and were the consequence of neglect by the ship's personnel. Consequently, the prevention of such accidents should proceed along the path of better assimilation of the ship's electrical equipment and monitoring its condition.

Another group of "thermal" reasons for accidents consisted of open fire and sparks during the performance of welding work on ships and the hot surfaces of the metal during welding. We examined several such accidents earlier. The catastrophes on the carrier "Constellation" and the loss of the military transport "Lafayette" were also connected with welding work. Accidents for these reasons occurred on the French light cruiser "Dyuge Turen" [as transliterated], on the German destroyer "Fridrikh In" [as transliterated] (1940), on the U.S. military transport "Sirius" (1972), and on other ships. Welding on a ship was often transformed into evil which led to great disasters. A number of measures have now been worked out which are directed toward the prevention of accidents for this reason. Among them are: enclosing and keeping combustible materials at a distance from the welding place, monitoring the air temperature in the welding area, ventilating the compartments, and a number of others. In the final analysis, these measures depend on the command of the ships and their crews as well as on the administration and working enterprises performing the work.

Above, in a statistical analysis of fires and explosions on ships, we pointed out that a number of accidents had occurred as a result of neglect by the personnel. This proposition requires some refinement.

The fact is that almost all types of fires are connected in one or another measure with omissions by the ships' crews. As we have seen, this also pertains to fuel fires, to the explosion of ammunition, to malfunctions in electrical equipment, and a number of other accidents. But with all these accidents oversights by the personnel, as a rule, were accompanied by shortcomings of another type, for example, of a structural or other nature. But there are shortcomings of the personnel of ships which stand out clearly, so to say, "in pure form." As example of this is the U.S. carrier "Croton" (1965) whose damage due to the personnel's neglect led to many human casualties.

Unquestionably, the majority of the accidents in the takeoff and landing of airplanes on carriers, of which there were a great number, are the result of the incorrect actions and omissions by the airplane and carrier personnel.

Many fires which occurred in various storerooms of ships such as, for example, the fire in the film library of the battleship "Tirpitz" in 1944 or the fire in the tire storeroom on the carrier "Forrestal" in 1969 or, finally, the fire in the electronic equipment storeroom of the Iranian destroyer "Artemis" in 1974 and similar fires were most often the result of oversights by the ships' personnel.

In the investigation and technical analysis of all such accidents, conclusions have been drawn concerning the necessity to raise the qualifications of the appropriate groups of ships specialists and to intensify demandingness toward the observance of fire-prevention discipline on ships. In a number of cases, it is necessary to conduct various measures of an organizational-technical nature or structural nature to exclude the possibility of repeating accidents through the fault of ships personnel.

Very often, fires also engulf the living quarters of ships whose combustible materials contribute to the spreading of the fire through the ship. In this connection the problem of "habitability and fire safety" is in the field of vision of foreign fleet specialists. In a number of cases, these two qualities which are important for a ship are contradictory and the requirements for them are far from always compatible.

The main direction in the solution of this problem is the elimination or significant reduction in combustible shipbuilding materials in the living quarters of ships. And although this problem is being solved for many years already, the effectiveness of the measures in the sense of their realization on ships is nevertheless not too high.

In recent years, a special program has been contemplated in this area in the U.S. Navy whose completion is planned in 1976. This program envisages the complete elimination of wood and wooden coverings, combustible curtains, drapes, rubber carpets, and other combustible materials from ships. It is planned to replace foam plastic mattresses with neoprene mattresses. To determine the degree of combustibility of materials, a certain criterion has been adopted in accordance with which the wood of red oak receives a value of 100 and asbestos slabs--0. A material which has a value of 25 or lower is considered noncombustible. Vinyl tiles which are used in civilian structures have a value of 65 in accordance with this criterion while the tiles used in the navy have a value of 9. Fiberglass rugs for living and service spaces will have a criterion value close to zero. It is intended to make curtains and drapery on naval ships from nomex--a material with a criterion value of 8-9.

The criterion values for various materials are determined by special tests. The impregnation of materials with noncombustible substances is widely employed. Fabrics and wooden materials, except for those which come in contact with food, are impregnated. In the British fleet, such impregnation is performed every six months. Electric cables are insulated using natural or silicone rubber or fiberglass with a protective jacket of neoprene. A number of requirements are being imposed on placement. For example, the space above the waterline, to include the upper decks, should be as free as possible of combustible materials. Combustible materials should be kept at a distance from intake vent holes of engine rooms. When storing important combustible materials below the waterline, it is important that they be located at a certain distance from watertight bulkheads.

Inflammable medical materials such as ether, alcohol, and so forth (except for daily supplies) must be stored together with fuels and lubricants below the waterline in compartments which are equipped or supplied with carbon dioxide systems. A decrease in the danger of fires is furthered by the placement of the clothing, bedding, and personal property of the crew members in metal lockers. To store materials which are capable of entering into chemical reactions with other materials, special storage places which meet certain requirements should be incorporated on ships.

A number of organizational-technical shortcomings are noted on ships. In particular, it is considered that the system for the storage and consumption of fuels and lubricants often does not correspond to the requirements which are in effect and does not ensure the fire safety of the ships in sufficient measure.

In order to reduce to a minimum the dangers which may arise when handling materials and with their storage on board ships, the U.S. Navy has worked out several general requirements:

1) areas for the storage of dangerous materials should be constantly dry and clean and provided with sufficient ventilation;

2) only people having special permission should be permitted to enter the places for the storage of dangerous materials;

3) the movement of inflammable materials from one place to another should be accomplished with the mandatory presence of the appropriate safety signs;

4) the use of plastic containers should be avoided if there is no confidence that the contents and the plastic are compatible from the viewpoint of fire safety;

5) the containers should be checked periodically for leaks, tightness of closing, storage period, and marking rules;

6) the performance of regular and the most frequent inspections possible to ensure the fire safety of ships as a whole;

7) the systematic conduct of fire-fighting lessons which are as close as possible to maximum conditions and with the use of respiratory devices in compartments filled with smoke;

8) ensuring the constant presence of damage-control parties on ships which are manned with specialists in fighting fires;

9) ensuring continuous and high fire-prevention vigilance on ships.

/Fire-fighting training of the personnel/. Great attention is being devoted to the training of crews for fire-fighting on ships. A system of schools and courses for the fire-fighting training of officers, petty officers, and seamen exists in the navies of the leading capitalist powers.

In the United States, such educational institutions are located in Philadelphia, Norfolk, Charleston, San Diego, and other bases. In a number of cases, training of personnel in damage control operations on the ship in general is conducted simultaneously in such educational institutions. Fire-fighting training usually encompasses four categories of fires: A--those extinguishable by water; B--combustion of fuel; C--fires due to electricity; D--the burning of phosphorous, magnesium, and high explosives. The latter category of fires has been introduced into the course of instruction in recent years. Skills which encompass both the individual practice in using carbon dioxide and powder fire extinguishers as well as the joint actions of teams are being worked out. The extinguishing of burning oil tanks with foam is demonstrated on the last stage. The stress in the fire-fighting training is placed on the use of the latest achievements in this field with use of the lessons from fighting fires on ships recently.

The entire crew receives skills in extinguishing fires, but the deck force undergoes increased training in this area. Furthermore, there are special subunits of qualified fire fighters on the ships. On big ships, models are used to instruct the personnel in fighting fires. Candidates for the post of ship captain undergo training in the new course on damage control, in which there is a special section on fighting fires, before beginning to perform their duties.

In the British Navy, schools in fire-fighting training are functioning in Portsmouth and Plymouth. All officers, petty officers, and seamen undergo training and, after a certain time interval, retraining in the area of fire safety.

We have examined structural and organizational-technical measures to ensure the fire- and explosion safety of ships. Let us now trace the actions of ships personnel in fighting fires which have broken out.

/Methods of fighting fires. The problem of evacuation/. The following methods of fighting fires were employed in the accidents and catastrophes which we have examined:

1) throwing burning aircraft and various ammunition overboard;

2) disarming airplanes and moving them to fire-safe places on the ship;

3) rendering ammunition harmless by removing their fuzes;

4) cooling ammunition with water from fire hoses;

5) flooding ammunition rooms and compartments which are adjacent to burning ones;

6) making cut-outs in decks with an autogenous welder to break through into adjacent compartments;

7) using water to extinguish fires in the lower compartments through holes in the decks which are located above;

8) cooling red-hot bulkheads and decks with water;

9) making compartments airtight and turning off the mechanisms of the boiler and engine rooms from the upper decks;

10) investigating compartments which are adjacent to burning ones, and so forth.

Virtually all of the fire-fighting equipment available on the ships was used here: the main fire main, the water protection system, mobile fire assemblies, fire extinguishers of various systems, autogenous apparatuses for cutting structural elements of hulls. Respiratory apparatuses, to include diving gear, were used to work in smoke-filled compartments.

Water-cooling from fire hoses was employed to protect people during fires. Helicopters, other combat ships, and rescue vessels rescued people from burning ships. There were cases of transferring people from burning ships to the shore using hoisting cranes (the "Constellation").

The basic difficulties in fighting fires were:

1) smoke in the interior compartments and on the upper decks of burning ships;

2) failure of illumination during fires;

3) sliding on decks when using foam to extinguish fires;

4) a shortage of fire-fighting equipment and the unsatisfactory condition of the equipment available;

5) damage to the equipment for fighting fires, explosions, fragments, and conflagrations and the absence of a sufficient reserve of equipment;

6) nonconformity of fire hose connections of ships and bases;

7) unsatisfactory designs of respiratory apparatuses which possess a poor protective capability and do not permit working in smoke-filled compartments for a prolonged period of time;

8) in a number of cases, the absence of devices and equipment to remove the "fire" water from the ships;

9) the melting of bulkheads made of light alloys, and a number of others.

A reduction in the effectiveness of actions by personnel in fighting fires was also caused by: decentralization of the direction of fire fighting in connection with the failure of communication equipment; the low level of service organization on a number of damaged ships; underestimation of the situation's danger and indecision in the actions of the personnel directing the fire fighting; tardiness of actions on ships and in bases; and poor knowledge of the ships and their communications.

To increase the safety of ships personnel during fires, a number of measures are being undertaken to ensure the evacuation of people from compartments engulfed by fire and smoke. This problem is considered especially acute for carriers and their numerous routes of communication in horizontal and vertical directions which are an extremely complex labyrinth in which it is difficult to find one's way under normal conditions, not to mention during fires which are accompanied by smoke-filled compartments and (frequently) failure of ships illumination.

It can be solved using the emplacement of special markers which facilitate the orientation of the personnel as they move about the ship. Such markers should be provided on exit routes to open sections of decks, primarily to the flight, gallery, and hangar decks.

Tests which were specially conducted showed that under conditions of heavy smoke in compartments even strong light sources are visible only for short distances. It was established that even with moderate smoke the light of flashlights of 21,000 candles is visible at a distance of no more than 2.0 meters while the light of quartz lamps of 45,000 candles is visible at a distance of about 2.5 meters. In this connection, other (nonlight) methods of orientation were also studied. In particular, touch systems for marking evacuation routes were tested but they did not provide the proper effect.

Tests showed that under conditions of light smoke and in the absence of illumination combined orientation systems are most acceptable. They consist of luminescent (luminous) and well-reflecting exit markers with the designation of evacuation routes and the locations of doors and hatches which are set out frequently (at a distance of about 1.5 meters). In individual, most difficult cases, it is recommended that lamps be set out to illuminate the markers and diagrams. Principles for the arrangement of markers on ships have been worked out [5, 56].

In addition to the markers, complete deck plans are provided which show the configuration of team routes of movement and the locations of entrances and exits (Fig. 31) [not reproduced]. Here, the deck plans must be made individually for each ship since even ships of the same type have a number of differences in the overall arrangement.

Realization of the new marking system on U.S. carriers is planned for the 1975/76 fiscal year for the carriers "Enterprise" and "Constellation" first of all. American specialists believe that the new marking system will attain its goal only if the crews have good knowledge of their ships and with systematic drilling under conditions as close as possible to emergency conditions.

In this program, attention is also turned to the individual protection of the personnel against fires. A new respiratory apparatus has been developed and adopted in the inventory. It is adjudged considerably more improved in comparison with the former one which was rejected on the basis of the experience of accidents and catastrophes which took place where many people died from smoke ("Oriskany" and "Franklin D. Roosevelt"--both in 1966, and others). The new respiratory apparatus which has undergone comprehensive tests consists of a plastic facepiece and cylinder with compressed air whose supply is intended for 8 minutes--a time sufficient to emerge on the flight deck of a carrier from any compartment. The apparatus may be donned and put into operation in less than 20 seconds while its weight is about 2 kilograms. The development of the new respiratory apparatus was preceded by a study of the products which are released during fires on ships, their toxicity, and other properties. The effect of carbon monoxide and other gases on humans was studied [38, 42].

[Pages 197-205]

§11. Analysis of Damage to Ships During Collisions

1. Statistical Analysis.

A statistical analysis was performed on the basis of an examination of 163 cases of collisions whose distribution is presented in Table 4 [not reproduced]. Of 93 cases of collisions without disastrous consequences, 61 are contained in the book. A list of 70 cases of ship collisions with a disastrous outcome is given in Appendix 2 [not translated], 6 of which are described in detail in this chapter.

Instances of damage to ships during collisions encompass a period of about 50 years. Exceptions are the "Hawk"-"Olympic" (1911) and "Shaw"-"Aquitania" (1918) collisions which it was important to include because of their instructiveness. Disastrous cases are presented for the time period since the beginning of the century as was done for ships fires and explosions.

An analysis of ships damage without disastrous consequences showed the following.

Three-fourths of the incidents of ship collisions occurred on the open sea or in gulfs, 13 percent occurred during collisions in bases and on approaches to them, while 9 percent took place in straits and rivers. Here, 44 percent of the collisions occurred during maneuvers and exercises while just as many took place under cruising conditions while executing various missions assigned by the command. Six percent of the collision cases occurred during participation in combat operations, and just as many during mooring and transferring fuel at sea from ship to ship.

The ship's period of service plays virtually no role here, as is shown by the following figures. Forty-seven percent of the cases involved the collision of ships with a service period of up to 10 years, and 41 percent involved ships with a period of service of from 10 to 20 years. About 12 percent of the cases involved ships which had been in service for more than 20 years.

Unfortunately, there are no sufficiently reliable data on the condition of the sea and weather or the time of day at which the collisions occurred. From the factual data which we have at our disposal, it follows that a rather large share of the collisions occurred during daylight (more than 20 percent) while 15 percent of the cases were collisions which occurred in the dark; there is no information on the remaining cases. Instances of ship collisions under satisfactory sea and weather conditions were rather frequent.

Cases of collisions which occurred with ships of 20 countries are distributed as follows: United States--49 percent, Great Britain--25 percent, Japan--11 percent, France--7 percent, Italy--5 percent, and the remaining countries--about 3 percent.

The scale of damage to ships during collisions and their aftereffects are of certain interest. Accidents show that in two-thirds of the cases ships received medium and heavy damage while in one-third of the cases damage was of an insignificant nature. Here, in almost 50 percent of the cases the ships required considerable repair and were out of action for a rather long period. Despite the comparatively large material losses, in these cases there were relatively few victims. Thus, for example, almost half the incidents involving ship collisions occurred virtually without victims while in 10 percent of the cases up to 10 or more killed were recorded. The number of victims was not established in the remaining cases (about 40 percent).

Just as with fires and explosions, the analysis of the loss of ships during collisions differs somewhat from the analysis of their damage without disastrous consequences. Used for the analysis of damage was a certain statistical sample which could not reflect all cases of ships damage; but in the analysis of disastrous cases, all cases of the loss of ships during collisions known to us were used. Furthermore, the time frame for the study was expanded both for the analysis of disastrous cases and for the analysis of fires and explosions, and cases of the loss of ships which occurred from the beginning of the century down to the present were taken.

The statistical analysis of ship collisions with disastrous consequences provided the following picture.

Approximately two-thirds of the ships which were lost were light ships; then come small combatants and minesweepers in equal proportion and auxiliary vessels (13 percent each) and, finally, 10 percent of the cases belong to armor-clads. This is completely understandable if we consider the relative survivability of the ships lost and the degree of their use.

More surface ships were lost in collisions with merchant ships (29 percent) and with armor-clad ships (23 percent), that is, more than half the losses of surface ships occurred during collisions with massive and relatively strong ships. In a comparatively small number of cases, ships were lost in collisions with light ships while an absolutely insignificant share of the disastrous cases (1 percent each) occurred in collisions with other ships, primarily with small combatants and minesweepers, which is also fully natural. The number of unknown cases (30 percent), where the class of ships with which the collision occurred is not specified, is great.

The "geography" of the countries of ships which were lost in collisions is not as broad as in the case of damaged ships: it encompasses 13 fleets of the world. Almost half the ships (46 percent) which were lost as a result of collisions belong to the British fleet and only 16 percent to the U.S. fleet. An equal share is occupied by ships of France and Japan (6 percent each) and by Germany, Italy, and Canada (4 percent each), then Denmark, the Netherlands, Norway, and Austria (3 percent each), and finally Argentina and China (1 percent each).

Just what are the dynamics of collisions of surface ships in the capitalist fleets and what are their trends?

Analysis of instances where ships were lost shows that two-thirds of them belong to two decades--the fifth (38 percent) and the second (27 percent). This is understandable if we consider that these include the corresponding data for World Wars I and II. About one-fourth of the cases belong to the first decade, which is connected with the still insufficient development of navigational equipment and, perhaps, the influence of the Russo-Japanese War. From two to four percent of the cases occurred in the other decades. Only two ships were lost during the last 10-15 years, of them the last being the Australian destroyer "Voyager" as a result of a collision with the Australian aircraft carrier "Melbourne" in 1964. Does this mean that the danger of collisions of surface ships has passed?

To answer this question, let us turn to the facts concerning damage to ships during collisions without disastrous consequences. And the facts are as follows. If 16, 12, and 7 percent of the collisions occur respectively in three decades--the third, fourth, and fifth, in the last two--the sixth and seventh--they were successively 20 and 30 percent, and for four years of the eighth decade (1970-1974)--14 percent. Here, four collisions of surface ships with various vessels occurred in 1973 alone. Among the "participants" in the collisions were one aircraft carrier, one destroyer, and two minesweepers. The collision of the U.S. guided missile frigate "Dahlgren" with the Italian tanker "Egeria" occurred in 1974. Both ships received damage which required repairs under shipyard conditions. In 1975, the carrier "John F. Kennedy" collided with the guided missile cruiser "Belknap." Unquestionably, this is very incomplete information on the collisions of ships in recent years. But the question posed above can be answered unambiguously on the basis of even these data: the danger of collisions of surface ships in foreign fleets not only has not passed, but it has a trend toward increasing despite the "absence" of disastrous cases. Two figures pertaining to the fifth decade attract attention, that is, in essence by the time of World War II: 38 percent disastrous cases and 7 percent of the instances of ships collisions without disastrous outcomes. It is instructive that during the war the collisions of ships ended primarily with the sinking of one of them since assistance for the damaged ship was not always in time. In the postwar years the number of damaged ships increased and the number of ships which were lost decreased since the damaged ship could be given the necessary assistance to keep her afloat.

§2. Reasons for Ship Collisions and the Nature of their Damage. Preventive Measures.

In the majority of cases of ships collisions which have been examined, especially those with a disastrous outcome, sufficiently complete and reliable information on the reasons for the collision is lacking, as a result of which a statistical analysis in this regard was not possible. However, on the basis of available factual data it can be concluded that the main reasons for the collision of surface ships in the foreign fleets were: poor communications and a low level of service organization on the ships, unskillful use of radar and other equipment, and the underestimation of the visual factor during the mutual maneuvers of ships and vessels. Noted in many cases were the insufficient training of ships' officers in navigation and their lack of knowledge of the sea-going, in particular, maneuver and inertial properties of the ships--friendly and "foreign"--and the laws for their coordination, especially at close distances.

In the emergency situations which arose, a large role was played by the careless, irresponsible attitude of officers and commanders of ships to their duties, a lack of understanding of the danger of events which were building up, a slow reaction to a changing situation, and the belated adoption of a decision in connection with this. The requirements of the regulations, manuals, rules, and instructions were often violated by the officers of the watch under various conditions of a ship's cruise.

The results of surface ship collisions were damage, at times extremely serious. During collisions at high speeds, there were cases of separation of the forward ends not only on light ships (the destroyers "Emmen," "English," "Frank E. Evans," and "Picking"), but also on heavy ships (the battleship "Wisconsin"). In such cases, the collisions often ended with a disastrous outcome (the destroyer "Fraser," the fleet minesweeper "Hobson"). The rammed ships suffered most often. With collisions, heavy damage was noted not only on the main hull, but also on the upper-deck superstructure, deck gun and torpedo systems and fire control instruments, mechanisms, electrical equipment, electronic equipment, and various ships compartments. Here, several ships compartments were flooded.

Collisions of surface ships and submarines occurred as a result of oversights by commanders of submarines ("Regent," S4, "Diablo") who did not follow thoroughly the surrounding situation on the surface of the sea prior to surfaving or did not submerge in time as well as a result of errors by the command of surface ships (the destroyers "Silverstein," "Giuseppe Missuri" [as transliterated]) which "unexpectedly" inflicted strikes on the submarines or "were unable" to avoid them. With such "encounters," as a rule, the surface ship emerged the "winner" while the submarines received heavy damage and were often lost. Six cases where submarines were lost in collisions with surface ships found reflection in the work (three submarines belonged to the United States, and one each to Great Britain, Japan, and Italy). It should be said that the timely adoption of measures on the part of even heavily damaged submarines provided favorable results, and the submarines were saved, staying afloat (the submarine "Bävern" in a collision with the cruiser "Fulgia"--see §8, paragraph 4 [not translated]).

Collisions of surface ships with merchant ships occurred with mutual "successes" which depended on the correlation of weights and the strength properties of the ships as well as on the speeds of movement and the angles of impact during the collisions. When big merchant vessels collided with light combat ships, including light cruisers, the latter received heavy damage ("Shaw") and were even lost ("Curacao"). And conversely, in collisions with small merchant vessels heavy combat ships inflicted serious damage on them and there were cases of their sinking (the loss of the Belgian fishing vessel "Franz Elza" during its collision with the aircraft carrier "Karel Doorman" in 1959). In cases of approximately equal correlations of ship and vessel dimensions and displacement, they received specific damage, as a rule preserving their floatability.

One of the reasons for the collision of surface ships with merchant vessels was their mutual suction. We already touched on this question in analyzing the cases of the "Hawk"-"Olympic" and "Curacao"-"Queen Mary" collisions. Collisions as a result of the mutual suction of ships and vessels in the cases which we presented caused various consequences. If, in the "Hawk"-"Olympic" case the ships were separated with comparatively minor damage and remained afloat, the collisions in the second case ended in disaster, as a result of which the cruiser was lost and several hundred men along with it. The nature and degree of damage to ships with mutual suction can be the most varied. This conclusion is also confirmed by other numerous cases of accidents which occurred for this reason. The phenonenon of ships suction has been studied rather completely on the basis of the analysis of a large number of accidents involving ships and the results of theoretical and experimental studies [59]. They were set forth partially above (§9, paragraphs 1 and 4 [not translated),

To avoid a collision in such cases, the overtaking ship must be at a safe distance from the ship being overtaken (see §9, paragraph 4).

Great significance is had by the possibility for a ship to change its direction of movement quickly, which is also provided by its turning qualities which depend on the ratio of the main dimensions and characteristics of the steering gear, that is, on the ship's structural elements.

From this, it follows that the prevention of ship collisions can be ensured by a complex of structural and organizational-technical measures as well as by the appropriate actions by ships personnel in situations which threaten collision.

From the experience of accidents and emergencies in foreign fleets, certain recommendations and requirements have been worked out which are directed toward reducing the probability of ship collisions and they are reduced to the following:

1) adopt in plans (and in realization during construction) of ships structural decisions which provide them with maneuvering elements which would permit a rapid change in the direction of ship movement in any situations;

2) improve the radar and other ships navigational equipment to ensure the reliable and precise determination of elements of the ship's displacement and location (surface ships and submarines);

3) raise the organizational level on ships and in naval forces with a clear demarcation of functional duties;

4) raise the level of navigational training of officer personnel on ships and in naval forces, especially of ship and force commanders, at the same time achieving their firm knowledge of the ships sea-going and other properties, the capabilities of navigational equipment, and the rules for preventing ship collisions, systematically conducting exercises and the critique of emergency cases where ships have collided;

5) strengthen discipline on ships, especially among the officers, achieving their strict implementation of the requirements set forth in official documents which are connected with ensuring ships safety in cruising;

6) increase vigilance on ships and intensify observation of the surrounding situation, especially under conditions of poor visibility and at night;

7) react quickly and act decisively in cases which threaten the collision of ships.

Another group of measures is connected with the striving to reduce the extent of ships damage during collisions and to reduce their possible aftereffects. Here, we have in mind measures which are adopted by commanders of colliding ships in situations of imminent collisions which are directed toward the possible reduction of the collision's effect in the sense of human and material losses (an example is the destroyer "Shaw"--see §9, paragraph 2 [not translated]) and measures to preserve the ship's survivability. As is known, a ship's survivability is ensured by a complex of three groups of measures (structural, organizational-technical, and the actions of the personnel during accidents) whose examination, however, falls outside the framework of this book.

In conducting a review of the measures which have been listed, it can be seen that, practically speaking, they are the same ones that existed many decades ago but with the consideration of new conditions. We will present two examples.

According to the evidence of the Americans, the rules for the passing of ships have existed for 25 centuries already. During the entire history of their existence, these rules have been continuously changed and corrected in accordance with the dynamics of collisions of ships and vessels. Our age is no exception. At present, international as well as national organizations are occupied with the problem of the collision of vessels. Many works have been devoted to it in which existing rules for preventing the collision of vessels are commented upon and new and newer recommendations for their improvement are introduced. Important scientific studies involving the efforts of many specialists are being conducted on these questions in various countries and computers and various models are used.

Without going into detail, we see on the basis of an examination of accidents and catastrophes with consideration of publications about them which are available that under contemporary conditions the recommendations and requirements for preventing ship collisions remained basically unchanged.

Another example. Exactly 100 years ago, in 1875, the British iron-clad "Vanguard" was lost in a collision with its fellow-countryman, "Aaron Duke." Three years later, the same fate was suffered by the German iron-clad "Grosser Kurfyurst" [as transliterated] which collided with "its own" iron-clad, the "Koenig Wilhelm," and another 15 years later, in 1893, the British iron-clad "Victoria" was lost as a result of its collision with the iron-clad "Camperdown."

In examining the circumstances of these catastrophes, two groups of shortcomings were established which contributed to the loss of these ships. Some shortcomings were connected with oversights by the command and officers (as well as the admirals) of the ships and forces which permitted these collisions. Other shortcomings which caused the loss of the ships as a result of the collisions were the consequence of design errors and organizational-technical omissions of the ships as well as of incorrect actions by the crews of the damaged ships. In the example of the "Victoria," this was shown in detail and brilliantly by Admiral S. O. Makarov, the founder of the teaching on ship unsinkability. On a model which was specially prepared by him, it was shown that in the absence of committed errors the iron-clad would have remained afloat and would not have been lost as a result of the damage which it received.

Many years and decades have passed since these three "famous" catastrophes, new classes of ships appeared, their equipment has changed fundamentally, generations of seamen and shipbuilders have changed many times, and considerable experience in the damage and loss of ships in wartime as well as in peacetime has been accumulated.

Despite all this, measures to exclude possible collisions of ships and reduce the effect of their actions on a ship remain unchanged in principle but with consideration of the increased cruising speeds of ships under conditions of the new technology which is employed on ships in the concluding quarter of our century.

The conditions are new but the requirements are old; to avoid collisions, to strive for the least amount of damage possible when collisions are inevitable, and to struggle for the life of the ship and its people in case of damage.

[Pages 230-237]

§2. Consequences and Lessons from the Disaster of a Squadron During a Typhoon

Thus, the secret became obvious. The confidential directive of the U.S. Pacific Fleet commander, Admiral Nimitz, "Lessons from Damage During a Typhoon," was published in the open press for all 12 years after it was issued [82]. This is a rare occurrence since materials on big accidents and catastrophes are usually published after several decades or are not even published at all.

Just what is the reason for the "hasty" publication of a directive which contains specific data on the catastrophe of a squadron's ships and the interesting conclusions and thoughts of one of the leading American admirals which follow from this greatest catastrophe?

The main reason, evidently, is concealed in the fact that questions of survivability and of ships safety in cruising have become one of the most important problems of the U.S. Navy. This is shown by many accidents and catastrophes of ships which have been occurring in the American fleet in the postwar years. Naturally, the best method for reducing the accident rate of ships is, first of all, the disclosure of the reasons as a result of which accidents occur, bringing them to the attention of those whom they concern. The reasons are always different: weak places in the ships construction and shortcomings in the actions of personnel, most often of the fleet's officers and admirals. It is for the very purpose of expanding the possibilities for instructing people from the lessons of accidents that the command of the U.S. Navy considered it possible and necessary to publish the conclusions from the catastrophe which occurred during a typhoon in 1944. One way or another, these materials were published in the central naval press of the United States in January 1956.

Just what are the circumstances, aftereffects, and lessons from this catastrophe which became one of the biggest at sea in our century?

The events developed on 18 December 1944 300 miles east of the island of Luzon when ships of the 3d U.S. Fleet, which had arrived to support the invasion of the Philippines by American troops, found themselves in an area close to the center of a typhoon and suffered considerable losses.

Three destroyers capsized and sank: "Hall," "Monaghan," and "Spence" (all built in 1934, total displacement respectively 1,800, 1,800, and 2,600 tons). These ships were returning from patrol having almost empty fuel tanks. The "Spence" was the first to find itself in difficult conditions; it had a damaged steering gear and became uncontrollable. Three hours later, it sank together with the majority of the crew (341 men). Then came the "turn" of the "Hall." It also lost control, stayed on the water for no more than an hour, and sank, having 201 men on board of which 62 managed to save themselves. The "Monaghan" was lost a half hour later with the majority of the crew (six out of 162 were saved).

The following nine ships received serious damage: the light cruiser "Miami" (1944, 12,000 tons), three light aircraft carriers--"Monterey" (1943, 13,000 tons), Cowpens" (1943, 13,000 tons), and "San Jacinto" (1943, 13,000 tons), two escort carriers--"Cape Esperance" (1943, 10,200 tons) and "Eltamakha" [as transliterated] (1943, 13,890 tons), and three destroyers--"Eyulin" [as transliterated] (1935, 1,700 tons), "Dewey (1935, 1,700 tons), and "Hickok" (1944, 2,500 tons).

Nineteen ships from escort ships to heavy cruisers and battleships received less serious damage.

Thus, 31 ships were lost and damaged; 146 airplanes on various ships were destroyed or damaged by fires, smashed or washed overboard. During the catastrophe 790 men died and 80 were injured.

Several destroyers which remained undamaged reported that their rolling reached 70° or more and that they almost capsized.

As a result, the 3d Fleet could not accomplish the operation of launching strikes against the island of Luzon at the planned time, that is, 19-21 December. The fleet's ships were forced to depart for the atoll of Ulithi for repair and to give the personnel rest. The fleet's operational actions were renewed 10 days later.

In assessing the losses from the effects of the typhoon, Admiral Nimitz pointed out in his directive that the losses of the 3d Fleet were greater than those which could have been expected as a result of any battle and he noted he [illegible] the resolve to instill in his officers the "necessity to understand the laws of a storm."

Just what lessons were learned from the catastrophe which occurred? First of all, in Admiral Nimitz' opinion, such heavy losses could have been avoided if the necessary measures had been undertaken ahead of time. Commanders at all echelons relied too heavily on weather summaries which were received from the fleet weather service center in Pearl Harbor but did not analyze data on weather conditions within a radius of 240-300 miles where the center of the typhoon was actually located. They did not pay proper attention to the first signs of the oncoming typhoon, and when it broke they could not bypass it (such attempts were made by individual groups of ships) since they did not have the necessary information on its path of movement.

The damage and losses to the fleet also increased because commanders tried to maintain assigned courses and speeds and even the assigned location of the ship during the storm. Ships commanders could not make a correct and timely estimate of the situation which had developed. They did not realize sufficiently that they had to abandon attempts to maneuver "correctly" and devote all attention to saving their ships and their crews.

The conditions for the fleet's passage, the behavior of the ships, and the actions of the personnel during the typhoon are characterized in the following manner in Nimitz' directive.

Visibility was within limits of 900 meters. The ships not only experienced a strong rolling motion, but they also moved with a constant wind list. Water entered various ships compartments through the air shafts and other openings in the part of the ships above water. The water level in these compartments (to include the engine rooms) reached 60-90 cm. However, no information was received concerning the disruption of the watertightness of the ships sides. The switchboards and electrical machines of various types often shorted out and burned. All this hampered control of the mechanisms and the ships, and the ships frequently lost control. Interruptions in the operation of various mechanisms, devices, and systems occured. Electric illumination failed. Radars and radio communication did not operate. Airplanes on carriers broke loose and struck each other, as a result of which fires broke out.

The wind and waves carried away masts, smokestacks, and davits and destroyed deck superstructure. The people could not secure equipments which had broken loose from their places or throw cargoes overboard when this was necessary for considerations of stability or for other reasons.

At the same time, the ships maneuvered right up to their sinking as they tried to maintain their places in formation in accordance with earlier instructions. One of the reasons for the saving of the destroyer "Dewey" was abandoning such an attempt which, in the situation as it had developed, would have greatly threatened the ship. Special attention is paid to the actions of the "Dewey's" commander. He altered his course by 40° to avoid a collision with the carrier "Monterey" which had stopped to put out fires in the hangars. The destroyer found itself in a more advantageous position on the new course. In combination with the energetic struggle of the ship's personnel to save the ship, these actions provided the possibility to save the ship from loss. The destroyers "Hall" and "Monaghan" which, as ships of the same type, possessed the same stability as the "Dewey," capsized. The reasons for the capsizing of the ships was seen in the fact that the ships, having empty fuel tanks, had not taken on ballast to compensate for the reduced stability. Furthermore, damage control was poorly organized on these ships. Thus, for example, the personnel abandoned their posts in panic in the engine rooms and the ships found themselves virtually at a standstill. The fact that the destroyer "Eyulin" also survived in addition to the "Dewey" is also attributed to the correct actions of the ship's captain.

Before capsizing, the destroyers lay on the leeside with a constant list of 50-80°, floating for some time before going to the bottom without thus having exhausted their reserve of buoyancy. This is also noted as a fact of insufficient stability of the destroyers under storm conditions.

Of two destroyers of the "Fletcher"-type, the "Spence" sank while the "Hickok" remained afloat. The "Spence" capsized and sank because its crew did not adopt measures ahead of time to eliminate free surfaces in the compartments and to right the ship by transferring fuel to eliminate the accidental list.

A special instruction on questions of stability states: "Measures must be adopted to ensure that commanders of all ships, especially of destroyers and smaller, have good knowledge of their ships' stability characteristics so as to adopt the corresponding safety measures consciously and in good time in regard to preserving the watertightness of the ships and in the matter of eliminating free surfaces of liquid which have a detrimental effect on the stability of ships" [82, page 87].

The catastrophe of the U.S. Pacific Squadron thus disclosed a number of substantial shortcomings of ships, first of all in regard to their sea-going qualities, unsinkability, and the survivability of individual types of equipment when compartments are flooded as well as shortcomings of the personnel in ships damage control, especially in the organization of damage control by the ships officer personnel. The directive stresses the proposition that no technical improvements can replace navigational skill and the ships crews sense of lofty responsibility for the assigned matter.

Commanders of ships are charged with the duty to prepare their own weather forcasts, and it is stressed that a local weather forecast should not diminish the significance of forecasts which are transmitted by weather stations. Any navigator deserves censure if he relies blindly on instrument readings alone. Censure is also merited by the commander who assumes that if the radio did not provide a warning about an oncoming storm, then all is well and local forecasts do not concern him.

Attention is directed to the responsibility of senior officers for the fate of small ships and for the actions of young officers.

It was proposed to commanders that they make a deep study of the sea-going qualities of their ships, especially of their stability and unsinkability and principles for righting a damaged ship by transferring liquid cargoes or by the employment of other methods which ensure the unsinkability of ships under storm conditions.

In the directive, special attention is devoted to questions of ensuring the survivability of ships. It is stressed that the main thing in the survivability of a ship is the competence of the ship's officers, their vigilance, and their keenness of observation and reaction to each change in the situation. Special attention is directed toward the necessity for firm knowledge of the basic documents which are connected with ensuring the survivability of a ship. In this regard, all documents which pertain here are listed.

Finally, one of the tasks of ships commanders and navigators is considered to be a detailed study of the contemporary condition for the movement of typhoons and the hydrometeorology of the sea or ocean on which they are to sail.

Such are the lessons which were learned from the catastrophe that was suffered by the U.S. 3d Fleet in the Pacific in December 1944.

The U.S. naval court which investigated the circumstances of the catastrophe found that "great errors were committed in regard to forecasting the typhoon's location and path of movement" [96, page 31].

Responsibility for the losses in the catastrophe was pinned on the commander of the 3d Fleet, Admiral Halsey and, to a lesser degree, on his subordinate officers. The court noted that errors were committed "under the influence of intense combat operations" and occurred "from the firm resolve to accomplish military requirements." On this basis, no judicial punishment followed. From the lessons of the 1944 typhoon, the storm-warning and weather-forecasting service was improved, according to reports in the American press. But the events which unfolded half a year later did not confirm this.

On 5 July 1945, when the war was already drawing to a close, the 3d U.S. Fleet again found itself in a typhoon's zone of action, this time in the area of Okinawa, and it suffered greatly from it. True, no ships were lost in this case, but serious damage was recorded by four aircraft carriers (including the heavy carriers "Hornet" and "Bennington") and three cruisers (on one of them--the "Pittsburgh"--the nose was torn away to a length of 30 meters, up to the first turret of the main caliber, and it was towed to the island of Guam for repair). Twenty-six other ships, including three battleships, received less significant damage. Seventy-six airplanes were destroyed and 70 damaged. Six men were killed and four seriously injured.

The fleet's losses from the effect of this typhoon, although they were less in comparison with the typhoon of 1944, proved to be sufficient to have a substantial effect on the course of the U.S. 3d Fleet's operations.

In this case, too, the naval court did not consider it necessary to bring in a decision for the judicial prosecution of the guilty, referring to the military services of the participants in the events.

The U.S. Chief of Naval Operations, Admiral King, evaluated the actions of the ships crews in both cases in the following manner: "In each case, there was sufficient information available to avoid the worst damage if the officers had reacted to the situation which developed with the skill of weather knowledge which should be expected from professional sailors" [96, page 32].

Judging from publications of the U.S. naval press, a number of improvements in the construction of ships were introduced on the basis of lessons from both typhoons. Considering that a reduction in the stability of many ships occurred as a result of the raising of their center of gravity during modernization work (especially when installing radar and antiaircraft armament), it was adjudged necessary to fill the fuel tanks with water ballast as the fuel is expended. The experience from the actions of the typhoons (especially in 1944) showed that a number of light ships suffered namely from the failure to satisfy this requirement. At the same time, measures were adopted to lighten the upper parts of ships and to improve the protection of electrical panels against sea water so that there would be no short circuits in case of emergency floodings.

In connection with the catastrophes which occurred, the development of new systems for "recognizing hurricanes" and forecasting storms was accelerated and the Navy's attention to meteorological questions which had formerly been neglected in considerable measure was intensified.

[Pages 236-240]

3. When a Group of Light Ships Ran Aground in a Harbor During a Storm

The night of 15-16 March 1956 in Newport (Rhode Island) is compared with 7 December 1941 (the Japanese attack on the U.S. fleet at Pearl Harbor) since during this night a rather large detachment of ships of the U.S. Navy was in great danger under the effects of a heaviest gale. The comparison with Pearl Harbor is not by chance because in both cases the "enemy" was unexpected and strong and the objectives of his action, ships, were in a state of rest and a great mobilization of forces and capabilities was required to reduce the aftereffects of the storm to a minimum.

The U.S. naval press pointed out that the catastrophe was an extremely instructive but expensive object lesson for the U.S. Navy. In the opinion of the Americans, the catastrophe was a general test of the organization of ships service on light ships of the Atlantic Fleet and a check of the correctness of the decisions made by the command and the expertise and bravery of the crews in executing damage control operations under storm conditions. In many cases, this struggle was conducted by officers who had never commanded a ship at sea and who operated using understrength crews which, in a number of cases, were inexperienced.

One of the main conclusions was: if there is no confidence that the officers who remain on a ship can control the ship independently under emergency conditions, the captain of the ship and his executive officer must remain on board and not go ashore as was the case on a number of ships in the case under consideration. The officer of the watch must be a qualified person who can replace the commander of the ship in the full meaning of the word. He must be able to control a ship during a joint cruise with other ships, get under way quickly, become oriented quickly under difficult weather conditions, get the ship under way in extreme cases, and so forth. The latter requirement follows from the fact that, in the absence of the ship's commander, the officer of the watch must often operate in stress situations (in the meaning of the sea and weather conditions). However, when the commander is present he has little opportunity to obtain independent practice in controlling the ship and people on the ship. It was noted that in this case much damage to the ships could have been avoided and the aftereffects would have been much less if the officers of the watch had been better trained for independent control of the ship under complicated conditions. The press points out that it is necessary to drill the watch officers constantly.

[Pages 251-273]

§17. Analysis of Ships Damage from Grounding and from Effects of Storms

1. Statistical Characteristics

A statistical analysis was performed on the basis of an examination of 162 cases where ships were grounded and of the effect of storms, the distribution of which is presented in Table 6 [not reproduced]. Of 46 cases of emergencies without disastrous consequences, 28 were examined in the book. A list of 116 cases where ships were lost due to grounding in presented in Appendix 3 [not translated], of which 24 cases are described in detail in this chapter. As was adopted for other types of accidents, cases of damage to ships encompass a period of about 50 years while disastrous cases are presented for the time since the beginning of the century.

Accident statistics on the grounding of ships and the effect of storms on ships are not very abundant. Nevertheless, some quantitative characteristics, especially concerning disastrous cases, which were presented in the accidents and catastrophes which we examined may, it seems to us, be of some interest. And we will begin with them.

First of all, it should be said that sometimes it is difficult to distinguish accidents connected with grounding and with the effect of a storm since, in a number of cases, these events are combined and grounding often occurs precisely in stormy weather which "helps" the ship to run aground. It is for this very reason that we are examining them in the same chapter. But if, nevertheless, the attempt is made to discriminate them, it turns out that in the cases which were examined ships were lost from "pure" grounding in 49 percent of the cases, from "pure" storm effects in 40 percent of the cases, and from combined effects in 11 percent of the cases. This division is arbitrary to some degree but it may useful if we consider that the nature of the damage and the reasons for loss are different under these effects just as the reasons for the accidents themselves and the possible methods for combating them (which will be discussed below) are different.

Among the ships which were lost, the greatest share is occupied by light ships (43 percent), the proportion is approximately equal (27 percent each) for armor-clad and auxiliary ships, and finally come small combatants and minesweepers which contain 3 percent of the cases.

Instances of the loss of ships from these types of accidents occurred in the fleets of 16 countries. The relative share of each of them is: the United States--34 percent, Great Britain--30 percent, France--10 percent, Japan--4 percent, Italy and Germany--3 percent each, and the remaining 10 countries--about 16 percent.

The dynamics of ships losses here appear as follows. A large part of the cases (37 percent) occurred in the fifth decade--the time of World War II; then come the first and second decades in an almost equal correlation (16-17 percent each). The third and fourth decades account for respectively 15 and 9 percent. About 6 percent of the cases remain for the last 25 years. Although the number of cases where ships were lost for these reasons is dropping relatively, they are occurring right up to recent years (the U.S. destroyers "Bache" and "Philip", the Australian patrol boat "Arrow".)

These types of accidents are often associated with large human losses. Although the number of victims was not published in 50 percent of the cases and in 25 percent it is known that the crews were saved, it was established that in the remaining 25 percent of the cases the number of victims reached several dozen men while in individual cases (the light cruiser "Niitaka," military transport "Angamos," training ship "Niobe," destroyer "Savarabi" [as transliterated], the torpedo boat "Tomoduru," the destroyer "Truxton," and the destroyer "Warrington") the number of victims was 100 and even several hundred men.

Among the cases of damage to ships (without disastrous consequences) armorclad ships occupy 44 percent and light ships--46 percent; then come small combatants and minesweepers (6 percent) and auxiliary ships (4 percent). Thus, it can be said that light ships receive damage and are lost almost equally (46 and 43 percent); heavy ships are lost more rarely than they receive damage without being lost (27 and 44 percent), which is completely natural if one considers the relative survivability of the ships. The same situation is found among small combatants and minesweepers (3 and 6 percent) since it is easier to heave them off. Concerning auxiliary ships, it was noted that the relative number of cases where ships were lost (27 percent) is considerably larger than the number of cases of damage (4 percent). This can be attributed to their comparatively low survivability and lesser value, and it is not always considered expedient to expend resources to save them.

The U.S. Navy's share is 59 percent, for Great Britain 17 percent, France 7 percent, Italy 2 percent, and the remaining countries about 15 percent.

In the dynamics of cases where ships were damaged, attention is attracted by the 1950's during which 44 percent of such accidents occurred. Among the damaged ships were the aircraft carriers "Valley Forge," "Randolph," and "Corregidor," the battleships "Missouri" and "Wisconsin," more than 10 American destroyers, and British ships. After this decade come the 1920's and 1930's (17 percent each), then the 1970's (13 percent for four years) and the 1960's (about 7 percent), and finally, the 1940's (2 percent). It is worth noting that in recent years instances of grounding again have an increasing trend. Thus, for example, in June 1974 the U.S. guided missile escort ship "Julius E. Furer," which was heaved off in a damaged condition by three tugs, ran aground in the area of the Netherlands. In December of the same year, two Australian patrol boats, the "Arrow" and "Ettek" [as transliterated], ran aground and received considerable damage. In these cases, the accidents were accompanied by human victims. The British coastal minesweeper "Brinton" received storm damage two years earlier, as a result of which the repair of the ship was required.

2. Reasons and Nature of Damage to Ships. Safety Measures

The data on the grounding of ships and the effects of storms on ships which we had at our disposal did not permit us to obtain quantitative characteristics on the reasons and nature of damage to ships during their accidents. But on the basis of an analysis of these data, we were able to obtain a sufficiently clear picture of the qualitative aspect of the problem, in which regard, separately for the grounding of ships and for the effect of storms which is not less important and, perhaps, more important.

The basic reasons for the /grounding of ships/ were:

1) errors in navigational calculations and plotting incorrect ships courses which were caused by the poor navigator training of officer personnel and the careless and, at times, irresponsible attitude of commanders and ships officers to their direct service duties (the cruisers "Raleigh," "Dauntless," "Edgar Kine" [as transliterated], "Boise," seven U.S. destroyers which ran onto the rocks as an entire force in 1923, the torpedo boat S2, and a number of others);

2) violation of the rules for company sailing of ships, the absence of a mutual check of courses and coordinates of ships location, and blind faith in the calculations of the flagship (the loss of the seven U.S. destroyers);

3) omissions connected with the incorrect maneuvering of ships (destroyer "Longshore"), the piloting of ships through dangerous waterways without an urgent need for this, in other words, with an unjustified risk (cruiser "Edgar Kine"), and arbitrary deviation from the course (destroyer "Truxton").

4) failure of mechanisms and other types of ships equipment, as a result of which the ships, becoming dead in the water and losing control, were carried onto the shoals by the current, often with serious consequences (the loss of the military transport "Vill' de Tamatav" [as transliterated]--1943, damage to the battleship "Wisconsin--1951," loss of the destroyer "Baldwin"--1961);

5) uncontrollability of ships under poor weather conditions or at night which, in a number of cases, was the consequence of incorrect actions by commanders and ships officers or the absence of the appropriate navigation and other equipment on ships (destroyers "Bache," "Baldwin," and others);

6) insufficient and, sometimes, even poor navigational-hydrographic and hydrometeorological service for the areas where the ships are sailing, the absence of reefs and other underwater obstacles on charts, and the absence of the necessary markers, as a result of which there were serious accidents (battleship "France," cruiser "Takoma," cruiser "Effingham").

Depending on the ships' class and type, speed and direction of movement, nature of underwater obstacle, and the grounding conditions the grounding of ships and their running up on the rocks caused various damage which led to various consequences right up to the loss of ships. Typical damage in these cases was: damage to the underwater part of the ship's hull, flooding of a number of its compartments and, in extreme cases, the break-up of the ship from its loss of overall strength. Associated damage was damage to the ship's power plant, ammunition magazines and other compartments for combat equipment, and to damage-control equipment.

Entire groups of ships and rescue vessels and, sometimes, even helicopters, were often called in to save ships and their crews.

In these cases, the entire arsenal of methods and equipment with which the salvage and rescue service of the fleets are equipped as well as methods and equipment for damage control operations on the damaged ship were used. Frequently, rescue operations were protracted over long periods or even ended in failure. The loss of more than 50 ships as a result of running aground and on the rocks and the large number of damaged ships speak for themselves.

Let us now dwell on several questions connected with the effects of storms on ships.

The main reasons for the loss of ships /under the effect of storms/ were:

1) the capsizing of ships from the loss of stability, which was the consequence of low stability parameters which were adopted in designing the ship (destroyer "Harusame." destroyer "Savarabi," torpedo boat "Tomoduru"-- all Japanese ships, the U.S. destroyer "Warrington") or as a result of the incorrect actions by ships personnel who permitted a reduction in stability during the service of the ship and did not take the necessary measures to restore it and to right the ships when they were damaged under storm conditions;

2) the break-up of ships from insufficient overall strength which was, on the one hand, the consequence of errors and oversights by the ships designers and builders (accepting overall strength parameters that were too low, failure to consider the suitability of ships and their equipment for the absorbing of storm effects), and on the other hand--the result of certain omissions by ships crews which did not adopt sufficient measures to preserve the watertightness of the ships hulls and their covers; this led to the flooding of compartments and an increase in the bending moments which were acting.

3) the landing of the ships in severe storm conditions because of a lack of reliable and timely information on the formation and movement of typhoons and hurricanes, which was the consequence not only of shortcomings in the work of the external information service, but also of omissions by commanders of ships and forces who did not prepare their own forecasts but relied only on what was ready and would be received externally (typhoon of 1944);

4) the lack of flexibility and sufficient initiative among commanders of ships and forces who tried to maintain speed and the relative position of the ships come what may without consideration of storm conditions which required them to save their ships and crews (typhoon of 1944);

5) the low level of service organization on the ships, as a result of which necessary safety measures were not adopted in a number of cases during the effects of storms not only on the open sea, but also in bases (Newport, 1956) and at anchorages at roadsteads, as a result of which ships received unjustifiably large damage and were often lost (cruiser "Niitaka," cruiser "Miguel de Cervantes");

6) the low level of damage control operations, as a result of which the personnel abandoned their battle stations and the ships were left dead in the water and no measures were adopted to right the ships ("Spence," "Hall," "Monaghan").

The following were noted when ships were damaged without disastrous consequences: disruption of the integrity of the main hull, destruction of the deck superstructures, flooding of individual ships compartments, and cessation of operation of various types of armament and equipment. As a result of such damage, ships went out of action for various periods. In the U.S. Navy, storm damage occurred during the 1950's and 1960's on aircraft carriers ("Randolph--1954, "Valley Forge and "Corregidor"--1959), destroyers "Rich," "Allen M. Sumner" --1959, "Daley"--1960), and other ships. In analyzing the behavior of ships of the British Fleet during World War II, the conclusion was drawn that many ships received serious damage under conditions of stormy weather. Here, the damage to flight decks of the carriers "Victorious" and "Illustrious" and a number of escort carriers was especially noted. According to the testimony of the British, in 1945 two American carriers of the "Essex"-type also received damage in the area of the flight decks and, primarily, in their forward sections.

On the basis of accident and catastrophe experience connected with the grounding of ships and the effects of storms on them and with consideration of equipment's contemporary development, foreign fleets are adopting a number of measures which are directed toward reducing the probability that such accidents may occur.

Some of the measures are common with those examined when discussing the questions of ship collisions (see Chapter II, §11). Furthermore, attention is directed toward the prevention of the landing of ships in the zones of movement of typhoons and hurricanes, for which their various characteristics are studied. The appropriate scope is being attached to this work in recent years since it is also of interest for the national economy of various countries. Recommendations have been worked out concerning the behavior of commanders of ships and vessels with the threat of formation and movement of typhoons and hurricanes. Measures are being adopted to improve the navigational-hydrographic and hydrometeorological service in the sailing zone of ships and forces.

In the group of measures to reduce the aftereffects from accidents which have occurred, attention is devoted to improving the organization and perfecting the procedure of rescue operations and to measures to increase the survivability of ships which are provided at all stages in the creation and service of the ship as well as under emergency conditions. In particular, attention is directed to improving the stability, unsinkability, and strength of ships and the development of damage-control equipment.

CHAPTER IV. SOME RESULTS AND PROBLEMS

§18. Accident Rate of Ships in Foreign Fleets

1. Accident Statistics

A general analysis was accomplished on the basis of an examination of 518 cases of accidents and catastrophes whose distribution by types of accidents and aftereffects is presented in Table 7.

The results from the loss of 242 surface ships for various reasons and their distribution by time, by fleets, and by classes of ships are reduced to tables and reflected on histograms.

It follows from these data that the loss of surface ships during the time period under investigation occurred primarily (about 48 percent) as a result of grounding and the effect of storms on them. The second main reason (29 percent) was the collision of ships with other surface ships, submarines, and merchant vessels, while the third reason (23 percent) consisted of fires and explosions. The largest number of instances where ships were lost (Table 8 and Fig. 59) occurs in the fifth (about 39 percent) and second (more than 21 percent) decades of our century when the World Wars occurred and in the period of which the intensity of the ships use and their number as part of fleets were the greatest.

Table 7. Number of Cases of Ships Damage and Loss by Types of Accidents Which Were Examined

Виды аварий (1)	Число случаев (2)		Всего (5)
	повреждения (3)	гибели (4)	
Пожары и взрывы	137	56	193
Столкновения	93	70	163
Посадка на мель и действие штормов	46	116	162
Всего (5)	276	242	518

Key:

1. Types of Accidents
2. Number of cases
3. Damaged
4. Lost
5. Total
6. Fires and explosions
7. Collisions
8. Grounding and effect of storms

Table 8. Dynamics of Loss of Ships

Годы (1)	(2) Причины гибели кораблей			Всего (6)	
	пожары и взрывы (3)	столкновения (4)	посадка на мель и действие штормов (5)	кораблей (7)	%
1900—1909	11	15	19	45	18,7
1910—1919	13	19	20	52	21,5
1920—1929	2	3	17	22	9,1
1930—1939	3	2	10	15	6,2
1940—1949	24	27	43	94	38,9
1950—1959	—	3	2	5	2,0
1960—1969	1	1	3	5	2,0
1970—1974	2	—	2	4	1,6
(6) Всего	56	70	116	242	100,0
(8) В %	23,2	29,0	47,8	100,0	

Key:

1. Years
2. Reasons for loss of ships
3. Fires and explosions
4. Collisions
5. Grounding and effect of storms
6. Total
7. Ships
8. In percent

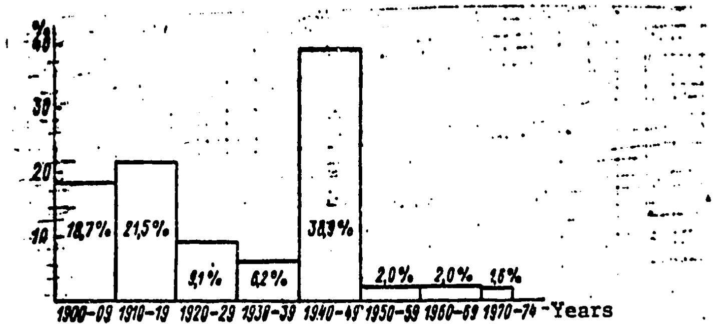


Figure 59. Relative Distribution of Cases Where Ships Were Lost, by Decades

A considerable number of cases also fall in the first decade; this can be explained by the still relatively poor development of navigational and other ships equipment. A reduction in the number of cases where surface ships were lost has been noted during recent decades. These indices are also rather stable for individual types of accidents. Does it mean that the cruising safety of ships in foreign fleets is such that there is no necessity to adopt measures for its improvement? The answer is unambiguous: no, it does not mean this. And here is why.

In the analysis of individual types of accidents, especially of fires and explosions on ships (and really, for other types of accidents), it was noted that the naval command of the capitalist powers is extremely concerned about questions of ensuring the safety of ships namely in recent years and is attaching great significance to these questions, of which we will be convinced below when examining the general measures to improve the sailing safety of ships.

Of individual world fleets, more cases of the loss of ships belong to Great Britain and the United States which together provide a little less than 60 percent. Then come Japan, France, Germany, and Italy. The share of these four naval powers is about one-fourth of all the ships lost. Seventeen percent remain for all the other fleets whose number is counted in dozens (see Table 9, Fig. 60).

These data are demonstrative in that they correspond basically to that specific significance which the ships of the fleets of various countries (especially of the leading naval powers) occupy in the total number of ships in the world naval fleet with several deviations of a nonessential nature. The proposition which has been expressed also pertains to individual types of accidents, which can be traced easily in Chapters I-III.

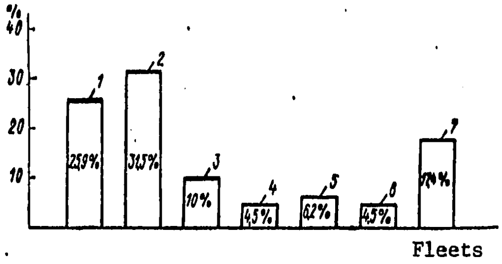


Figure 60. Relative Distribution of Cases where Ships were Lost, by Fleets: 1- United States; 2- Great Britain; 3- France; 4- Germany; 5- Japan; 6- Italy; 7- other fleets.

Quantitative characteristics of cases of loss for individual groups and classes of ships are illustrated by Table 10 and a histogram (Fig. 61), from which it follows that the greatest share is occupied here by light ships (43 percent); behind them follow armor-clad ships (without carriers) whose share is about one-fourth of the cases. It was pointed out above that during all the years only one case (0.4 percent) of the loss of an aircraft carrier under noncombat actions was recorded. Of the remaining classes of ships about 23 percent belong to auxiliary ships and 9 percent belong to small combatants together with minesweepers. These summary data are completely explainable if we consider the relative survivability of ships and the degree of their use.

Table 9. Distribution of Cases of Ship Losses by Fleets of the World

Флоты (1)	(2) Причины гибели кораблей			(6) Всего	
	пожары и взрывы (3)	столкновения (4)	посадка на мель и действие штормов (5)	кораблей (7)	%
(8) США	13	11	39	63	25,9
(9) Англия	9	32	35	76	31,5
(10) Франция	8	4	12	24	10,0
(11) Германия	5	3	3	11	4,5
(12) Япония	5	4	6	15	6,2
(13) Италия	4	3	4	11	4,5
(14) Другие флоты	12	13	17	42	17,4
(6) Всего	56	70	116	242	100,0
(15) В %	23,2	29,0	47,8	100,0	

Key:

1. Fleets
2. Reasons for loss of ships
3. Fires and explosions
4. Collisions
5. Grounding and effect of storms
6. Total
7. Ships
8. United States
9. Great Britain
10. France
11. Germany
12. Japan
13. Italy
14. Other fleets
15. In percent

An analysis of damage to ships without disastrous consequences was performed on the basis of an examination of 276 cases of which fires and explosions occupy about half the cases, collisions about one-third, while the remaining cases (less than 17 percent) are grounding and the effect of storms. These figures evidently reflect the frequency of types of accidents on surface ships. At the same time, if they are compared with cases of loss, they indicate that surface ships remained "alive" more often with fires and "survived" least of all during grounding and the effect of storms. Just as in cases of loss, here collisions occupied an intermediate position.

Without presenting all the statistical data obtained here, we will only note the following. During the last 10-15 years all three types of accidents and

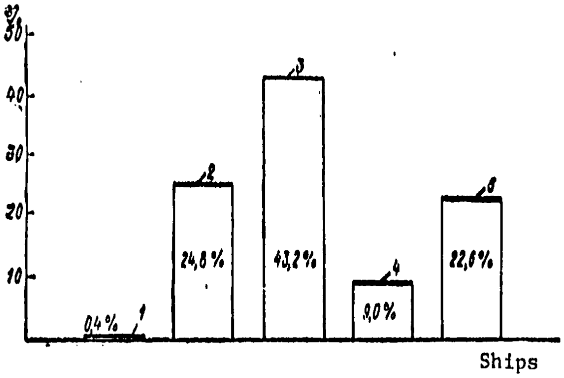


Figure 61. Relative Distribution of Cases of Loss by Groups and Classes of Ships: 1- carriers; 2- armor-clad ships (excluding carriers); 3- light ships; 4- combat boats and minesweepers; 6- auxiliary vessels

Table 10. Distribution of Cases of Loss by Groups and Classes of Ships

Группы и классы кораблей (1)	(2) Причины гибели кораблей			Всего (6)	
	пожары и взрывы (3)	столкновения (4)	посадка на мель и действие штормов (5)	кораблей (7)	%
(8) Броненосные корабли (без АВ)	22	7	31	60	24,8
(9) Авианосцы	1	—	—	1	0,4
(10) Легкие корабли	10	44	50	104	43,2
(11) Боевые катера и минно-тральные корабли	8	10	4	22	9,0
(12) Вспомогательные суда	15	9	31	55	22,6
(6) Всего	56	70	116	242	100,0
In %	23,2	29,0	47,8	100,0	

Key:

1.	Groups and classes of ships	7.	Ships
2.	Reasons for loss of ships	8.	Armor-clad ships (excluding carriers)
3.	Fires and explosions	9.	Carriers
4.	Collisions	10.	Light ships
5.	Grounding and storm effects	11.	Combat boats and minesweepers
6.	Total	12.	Auxiliary vessels

catastrophes of surface ships occurred without disastrous consequences. However, the determining type of accident consisted of fires and explosions, especially on carriers of the U.S. Navy.

2. General Reasons for Accidents and Catastrophes of Ships and their Consequences

Despite the specific nature of each type of accident and individual breakdown incidents, something common is observed which is inherent to many accidents and catastrophes regardless of their types and specific manifestations. This common factor consists of basic shortcomings which, in the final analysis, give rise to these accidents and frequently lead to serious consequences. The shortcomings being discussed can be divided into two groups.

One group includes shortcomings of a structural-technical nature which occur in the process of creating a ship, during its design and construction. In the course of designing a ship as a whole and its individual components (weapons, mechanisms, devices, systems) mistakes and omissions are committed which are connected with the failure of the plans to correspond to the conditions of the mission and the rules for designing and building ships as well as with failure to consider ships sailing practice and conditions. In executing the plan, technical decisions may be made which are not sufficiently substantiated by calculations and experiments. But it would be incorrect to consider all errors at this stage of a ship's creation as the fault of the designing organizations alone. There are omissions which follow from the nonconformance of missions assigned by the Navy's organs to the ship's conditions of service or from the unreality of the missions which contain incompatible requirements. As a result of errors and omissions in designing, the ships which are built possess insufficient stability, unsinkability, maneuverability, and strength or they have a low level of explosion- and fire safety and are not provided with sufficient damage control equipment.

In building ships, mistakes are also committed which may lead to various accident incidents. In this case, errors are encountered which are connected with the nonconformance of the ship which has been built to the plan, with the employment of poor-quality materials, with the performance of substandard work by the building yard or its contractors, with the employment of incorrect technology in building the ship, and with failure to observe building rules. Insufficient monitoring when building a ship and the absence of necessary full-scale tests conducted at the shipyard itself and under sea conditions are additional sources for the occurrence of accidents in the course of a ship's sailing and service. And here, it should be noted that in addition to industrial organizations responsibility for construction errors and shortcomings is also borne by the naval organs which are observing the course of the ship's construction and are participating in its tests.

It will be appropriate to mention that the incorrect organization of construction work and repair-modernization work led to accidents and catastrophes which occurred at shipyards and in docks and, consequently, to material and human losses as well as to more or less prolonged delays in putting the ships into service.

Shortcomings which are noted in the course of the ship's service under regular sailing conditions as well as under emergency conditions belong to the other group. Under regular (standard) sailing conditions accidents could appear as a result of: the insufficient state of training of the crews both in regard to knowledge of the properties of their ship and the environment as well as in the matter of mastering the ship's equipment and methods for its operation; the unsatisfactory organization of service on ships, especially in regard to planning the instruction and distribution of the personnel and the clear establishment of their functional duties; the low state of discipline of all categories of personnel, a careless and irresponsible attitude toward the accomplishment of their official duties, and violation of the requirements of guidance and regulating documents; carelessness in the performance of service and the absence of the proper vigilance, foresight, and precaution; failure to consider the environmental conditions.

A large role in accidental incidents and their aftereffects was played by the unsatisfactory hydrometeorological and navigational-hydrographic support of ships cruises. These were expressed in the tardy and, at times incorrect forecasting of the sea's condition and the movement of the winds; in failure to plot underwater obstacles and various reference points on charts and in navigational aids and manuals; and by failure to provide the necessary hydrographic markers of water areas and ships routes of movement.

In emergency situations, the increase in material and human losses and, at times, the losses of ships were furthered by the personnel's lack of knowledge of a ship's properties and equipment and damage control methods; the crews' low morale and discipline and a panic attitude which reigned on ships and vessels at times; unpreparedness and insuffiency of damage control equipment; insufficient consideration of the danger of accidents on the part of ships' command and the unsatisfactory organization of damage control operations; and nonconformance of the measures adopted to the conditions of the developing emergency situation.

The general shortcomings which were the basic reasons for ships accidents and which led to serious consequences are presented in the diagram (Fig. 62).

In this connection, it seems of interest to present some data here concerning the accident rate of ships of the U.S. Navy which have been published recently (106].

Table 11 contains information on the reasons for accidents on ships of the U.S. Navy which occurred during the 1970/71 and 1971/72 fiscal years. It follows from the tables that almost half the accidents occurred due to the personnel's incorrect actions and omissions, about one-fourth occurred for reasons of a structural nature and, if we exclude indefiniteness, then the remaining reasons account for 17 percent.

The absolute data of the table which indicate the large scales of accidents on ships of the American fleet are also interesting. If we consider here that (as the Americans themselves assert) the actual number of accidents is considerably larger since about one third of the Navy's ships did not report about accidents which occurred at all, the scales of the accident rate increase significantly.

Table 11. Reasons for Accidents on Ships of the U.S. Navy (1970-1972)

Reasons	Number of Accidents	% of Total Number
Incorrect actions and omissions by personnel	1880	49.7
Structural shortcomings and materials	881	23.2
Effect of the environment	304	8.0
Dangerous conditions and objects	168	4.4
Employment of incorrect methods	152	4.0
Consequences of preceding accidents	139	3.7
Undetermined	263	7.0
Total	3787	100.0

As regards the aftereffects of accidents, according to official data in 1972 alone material losses in the U.S. Navy as a result of ship accidents were 11.5 million dollars and, in this connection, the ships lost more than 4,300 days for the conduct of repairs. The actual figures which characterize the losses are many times greater not only because ships and forces do not always report accidents, but also because far from everything known reaches the press.

This is indicated by another source [104] which points out that in 1972, in cases which "did not land in newspaper headlines," the U.S. Navy lost about 700 men in accidents while about 5,000 were injured. Despite the fact that the war in Vietnam still continued, 15 times more seamen were lost outside of combat circumstances than under combat conditions. A curious statistic is presented in this work which indicates that altogether during the period 1961-1972 noncombat losses in the U.S. Navy exceeded combat losses by a ratio of more than 6:1.

This, in general, is the picture of accidents and catastrophes of ships in the capitalist fleets.

Let us now see what ways are planned to reduce the accident rate of ships and to increase their safety.

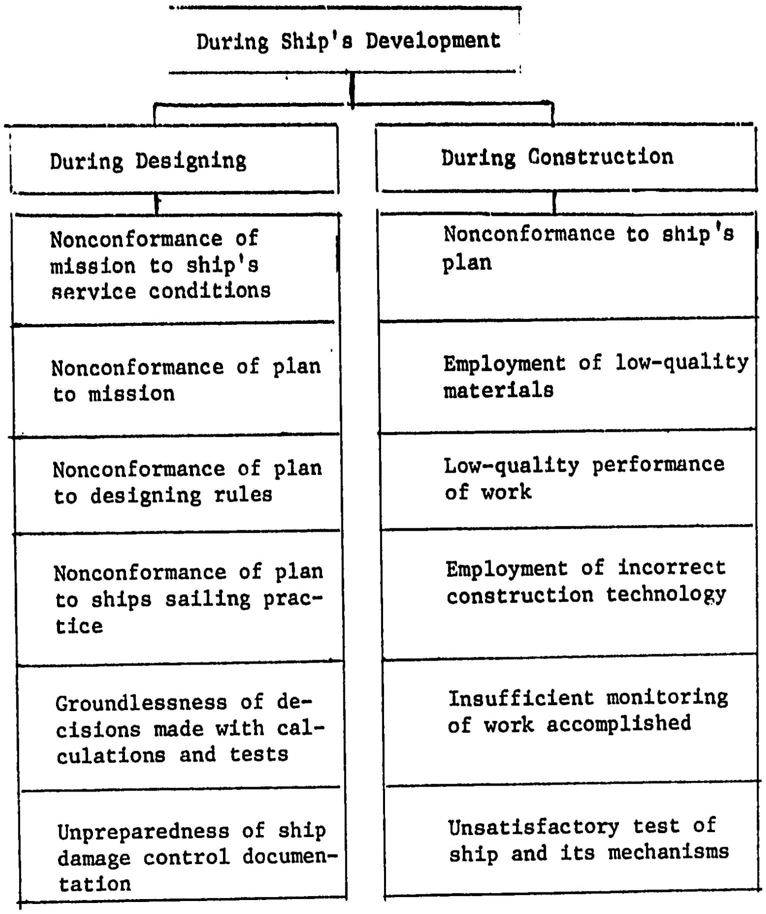
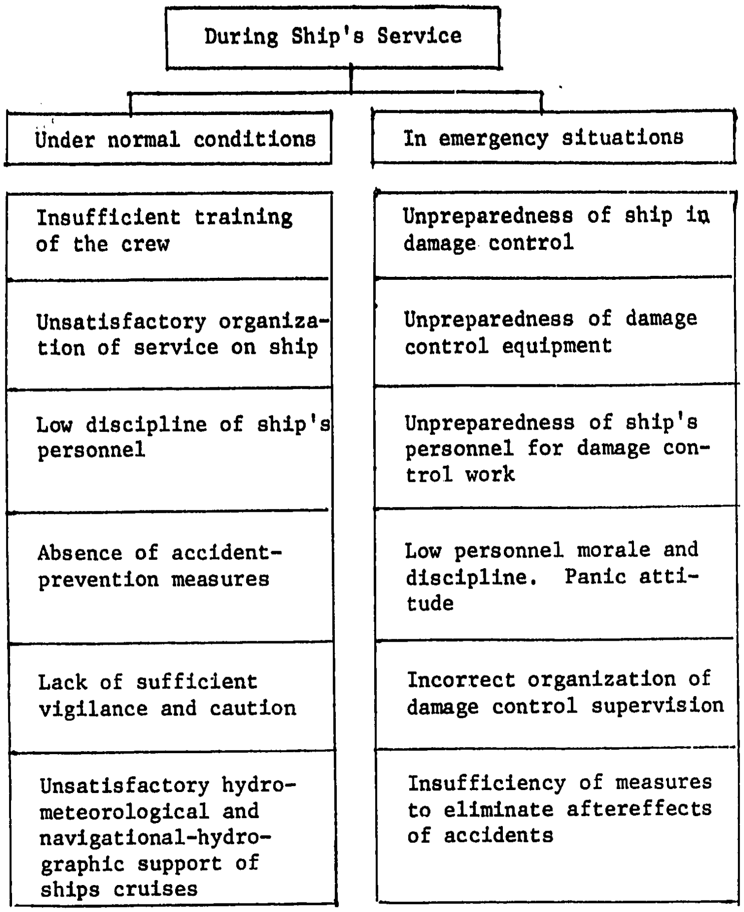


Figure 62. General Shortcomings--Basic Reasons for Ships Accidents and Catastrophes [figure continued on following page]

[Figure 62 continued]



During Ship's Service

Under normal conditions	In emergency situations
Insufficient training of the crew	Unpreparedness of ship in damage control
Unsatisfactory organization of service on ship	Unpreparedness of damage control equipment
Low discipline of ship's personnel	Unpreparedness of ship's personnel for damage control work
Absence of accident-prevention measures	Low personnel morale and discipline. Panic attitude
Lack of sufficient vigilance and caution	Incorrect organization of damage control supervision
Unsatisfactory hydrometeorological and navigational-hydrographic support of ships cruises	Insufficiency of measures to eliminate aftereffects of accidents

§19. The Problem of Ship Safety and Ways for its Solution

The growth in the accident rate in the navies of the capitalist countries, which was accompanied by extremely tangible human and material losses, led to where it was necessary to devote more and more attention to questions of increasing safety before they grew into a state problem, in particular in the United States.

This problem acquired special urgency in the 1960's when a great fire disaster broke out on the aircraft carrier "Constellation" (1960); then, when the "first-class" nuclear submarine "Thresher" was lost under "secret circumstances," and when large catastrophes occurred several years later on the carriers "Oriskany," "Forrestal," and "Enterprise" (1966-1969). These events were accompanied by a large number of accidents and catastrophes in naval air forces.

The numerous commissions which functioned during the "period of accidents and catastrophes" examined and resolved the problems which pertained to each accidental incident, and some of them were charged with the development of recommendations of a broader nature which already pertained to a class of ships as a whole (submarines, carriers). But all these were individual tasks of the fleet safety problem. In the course of the commissions' work, it began to be learned that the origin of a number of accidents was caused not only by the oversights of individual people and ships, but also by the command of forces, fleets, and the Navy as a whole. Since structural shortcomings of ships were the source of many accidental incidents, industrial enterprises and firms and scientific and other organizations which support the Navy began to be drawn into the orbit of this problem. A number of catastrophes received a great public response, and their results became a subject for discussions in public organizations and state organs. Thus, they ceased to be the Navy's "internal matter". The circumstances which developed forced the Naval command to adopt certain radical measures with the goal of reducing the accident rate and increasing the safety of naval objects, in particular, ships.

Also in this connection, in 1969 a special "Naval Safety Center" was organized in the United States. Its goal is "the establishment of an effective and energetic program to prevent accidents in order to raise operational readiness and reduce the number of human victims and injured as well as the material losses of naval units and forces from random causes" [106, page 56]. The center's goal was formulated in this form in 1970 by the Chief of Naval Operations of the U.S. Navy. Norfolk was selected as the center's base and its strength was established at 300--servicemen and civilians. Its structure consists of four directorates--surface ships, submarines, naval aviation, and coast defense--and several departments. A special safety program was worked out for the implementation of which naval units and forces as well as "external" (as regards the Navy) personnel and equipment are widely involved in addition to the center's forces.

One of the basic types of activity is the prevention of ships accidents through systematic and "surprise" inspections to eliminate dangerous conditions. Here, a dangerous condition is defined as any condition in which the occurrence of an emergency or accident is most probable. For example, poor maintenance of materiel, the absence of protective and preventive systems, the cluttering of compartments, insufficient illumination, or the unsatisfactory condition of the atmosphere--all this falls under the concept of "dangerous condition." The inspection is carried out by the newly formed safety inspectorate.

Here, we should indicate a new, broader interpretation of an accident which has now been adopted in the U.S. Navy. Now, an accident or accidental incident is defined as any unplanned act or event as a result of which damage occurs to the equipment or cargo of a ship as a whole or personnel are injured or killed. Thus, an accident includes all unforeseen cases "from point to point" which are connected with a ship's personnel and equipment. This "new concept" is substantiated primarily by economic considerations. In the opinion of U.S. naval specialists, it is important not only to prevent the failure of ships and their crews, but there should also be the striving to eliminate the necessity for repair or, in any case, to reduce the cost of repair since virtually all "unplanned events" which impair the "mission" of the ships lead to financial expenditures in the last analysis. A "viable safety program" and its implementation should lead to an effective reduction in the probability of the outbreak of accidents and, consequently, to a savings in budgetary resources released to the Navy.

In this connection and considering that the system of information on ships accidents which existed until recently was adjudged complex and not meeting contemporary requirements, the center worked out and put into effect a new procedure for the collection and processing of data on various accidents. The data are stored in the memory of the computers with which the center is equipped. Rear Admiral Nelson, the chief of the Naval Safety Center, called the computer system the "watchdog" which stores and analyzes data on the Navy's safety, guarding its installations against dangers.

The center revises and republishes manuals, instructions, and rules from the standpoint of increasing the safety of the personnel's actions. And again, any deviation from the generally accepted method of work which increases the probability that an accident may emerge is called a dangerous action (working without sufficient knowledge or training, working at a dangerous speed, the use of substandard materials, structural elements, or equipment, distractions, and so forth).

The center is conducting important propaganda work. It publishes a number of journals. Six such publications which published directive and educational materials were counted in 1975. The center publishes books and prepares and distributes films connected with safety questions.

In 1973, the center developed and proposed a "new" approach to ensuring ship safety called the "safety system." The authors employed a systems approach to the designing of ships and their equipment with emphasis on accident prevention. Here, the "system" was intended for the ship's entire period of service. This system was employed in the design and construction of the submarine SSN-688 (of the "Sturgeon" type), the destroyer DD-963 ("Spruance"), hydrofoil guided missile boats, and other ships.

Considered to be most difficult is the elimination of accidents caused by personnel of the ships (the main reason for all accidents on American ships) which was indicated above. It is proposed that biorhythmic records which establish those who are guilty of accidents be used in the analyses of accidents on ships to solve these problems.

Such are some of the new approaches to solving the problem of ship safety, the expediency and effectiveness of which will be able to be judged after checking them in practice. At the same time, "traditional" methods which have been modernized with consideration of the experience from recent ships accidents and catastrophes are not being discarded, either.

On the basis of this experience, certain recommendations, requirements, and measures have been worked out which are directed toward reducing the accident rate and increasing the security of ships under any sailing conditions. They are reduced to certain measures--structural, organizational-technical, and actions by the personnel.

Specific measures as applicable to various accidents were examined in the corresponding chapters. For all types of accidents, they are directed toward the elimination of the general shortcomings which were discussed above and toward a further improvement in all fields which ensure ship safety.

In this regard, we should dwell briefly on some general measures for ensuring ship survivability. Especially as much more attention has begun to be devoted to this question abroad than formerly. This pertains especially to the training of ships crews for damage control. For example, in the United States a considerable number of various courses and schools on training the personnel in damage control and fire fighting are functioning. Now 78 such educational institutions which are located in bases on both coasts of the United States--on the Atlantic and Pacific Coasts--are counted, of which 33 are for damage control, 27 are for fire fighting, and 18 are for antinuclear defense. The center for damage control training is Philadelphia where there are 6 officer courses and 13 for training seamen and petty officers.

The tasks are continuously becoming more difficult to improve the training of the personnel, approaching an actual situation.

Under ship conditions, attention is devoted to improving the cooperation of departments in damage control and concentrating the attention of the commander of the damage-control organization (on big ships) on his own problems, freeing him from secondary functions, on studying the experience of accidents and ships damage, and on stabilizing the composition of repair parties.

A number of publications on questions of ship survivability have appeared in recent years. Some specialists [100] believe that many accidents and catastrophes result from the fact that proper attention is not paid to questions of ensuring survivability and they pose the question of the necessity to organize a special survivability service whose functions should be: coordination of systematic preventive measures; technical servicing and repair of ship damage-control equipment; the conduct of exercises on damage control and the creation of effective damage-control organization; coordination and distribution of requisitions for repair work; and the maintenance of documentation on structural changes which occur on a ship during its operation and repair. Here, reliance should be placed on preventive measures which prevent an accident and not on eliminating its aftereffects. Such statements are not individual statements and they agree with the line which the safety center is conducting.

Conclusion

Accidents and catastrophes occur as a result of fires and explosions on ships, collisions, the effects of storms, and the running of ships aground and on the rocks, the aftereffects of which are often commensurate with the aftereffects from combat effects on ships and, in a number of cases, they surpass them considerably.

The basic reasons for accidents and catastrophes which occur from noncombat effects on ships or are concealed in structural-technical shortcomings of ships are the consequence of errors and miscalculations which are committed during designing and construction or are connected with errors and oversights which occur in the course of using ships under their normal service conditions as well as in emergency situations. Analysis shows that as applicable to surface ships and auxiliary vessels of the fleets of capitalist countries, reasons of an operational nature predominate substantially over reasons of a structural-technical type.

These conclusions, which were drawn on the basis of an examination of accidents and catastrophes that occurred over several decades, have a rather stable nature and also remain valid for contemporary conditions. The rapid and qualitatively new development of naval equipment has had a contradictory effect on the accident rate of ships and on ensuring their survivability and safety. On the one hand, the development of new equipment led to the possibility of creating new means and methods to prevent accidents and combat them, having a beneficial effect on ensuring their survivability and safety. On the other hand, this development was connected with the complication of equipment and the incomplete work on its individual assemblies and, with the breakdown of the "man-equipment" system under new conditions, was the reason for a number of accidental incidents. Overstraining of the crews under conditions where the ships were on operational service (or when conducting combat operations) was an additional reason for the outbreak of accidents.

The totality of all these factors was the reason why, in a number of fleets and especially in the U.S. Navy, cases of accidents and catastrophes became more frequent during the last decade to such a degree that questions of ships safety (surface and submarines) developed into a problem of State significance. Here, in the United States special attention began to be paid to ensuring the safety of carriers and submarines as the leading classes of ships.

A number of radical measures have been implemented in the United States in recent years to increase safety. A special Naval Safety Center has been organized with a staff of several hundred people. A broad program has been worked out to ensure safety for the implementation of which both naval organs as well as scientific and industrial organizations which are not part of the Navy have been involved. In addition to intensifying traditional measures of a structural-technical and organizational-technical nature, new methods are being evolved to increase safety which are being employed in the designing of ships. They envisage ensuring the safety of a ship over all stages of its service. Great attention is being devoted to reducing the accident rate of ships personnel who are, according to the American data, the main reason for accidental incidents. A new system of information has been developed for this purpose on the basis of which accidents are analyzed comprehensively to generate recommendations for the continuous improvement of ships safety service.

According to data in the U.S. naval press, the totality of the measures being conducted is providing noticeable results. At the same time, the Americans acknowledge that the degree of their effectiveness may be established with time as experience in new directions is accumulated.

[Pages 288-291]

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