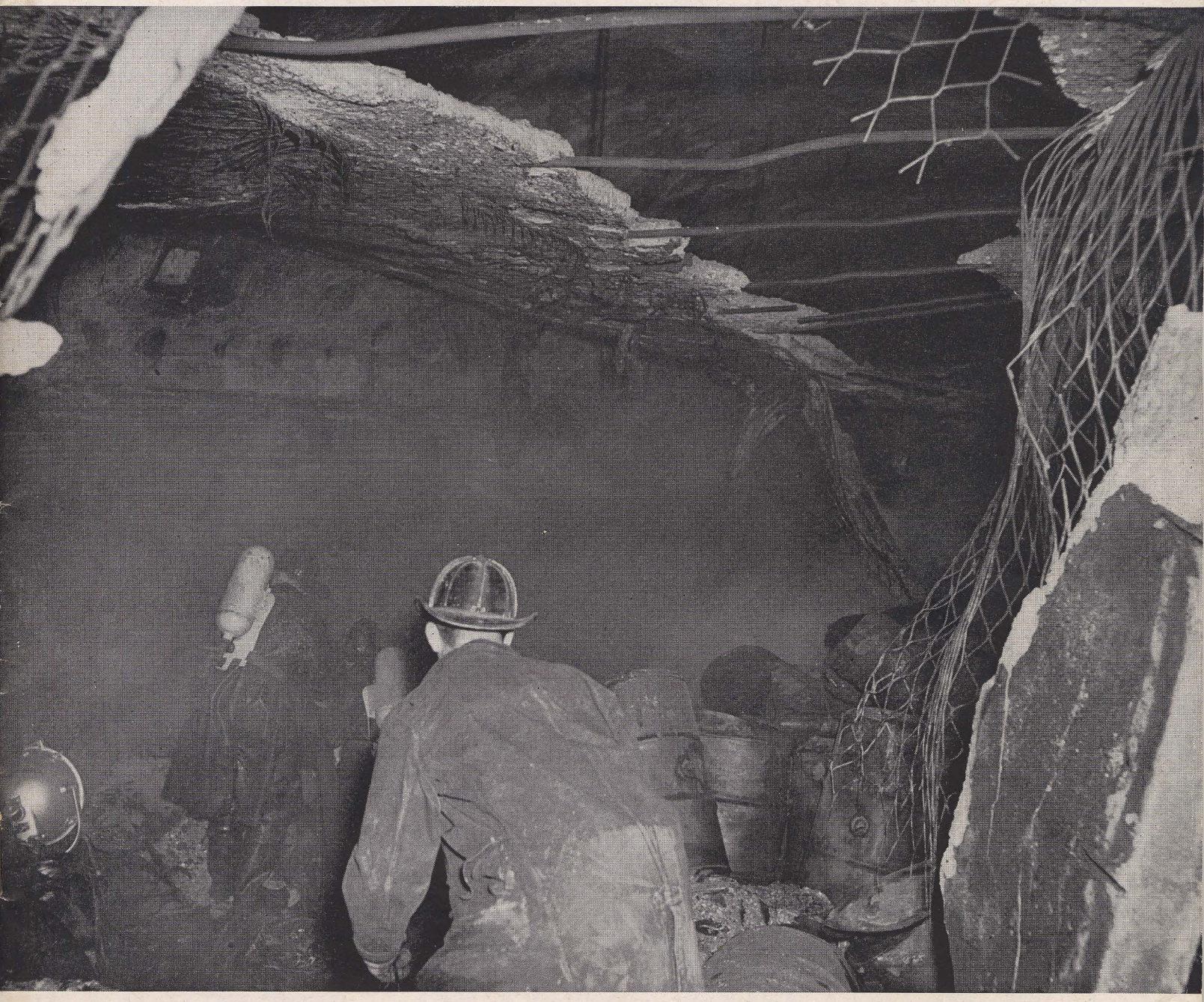
THE HOLLAND TUNNEL CHEMICAL FIRE

New Jersey — New York

May 13, 1949



Report by

THE NATIONAL BOARD OF FIRE UNDERWRITERS
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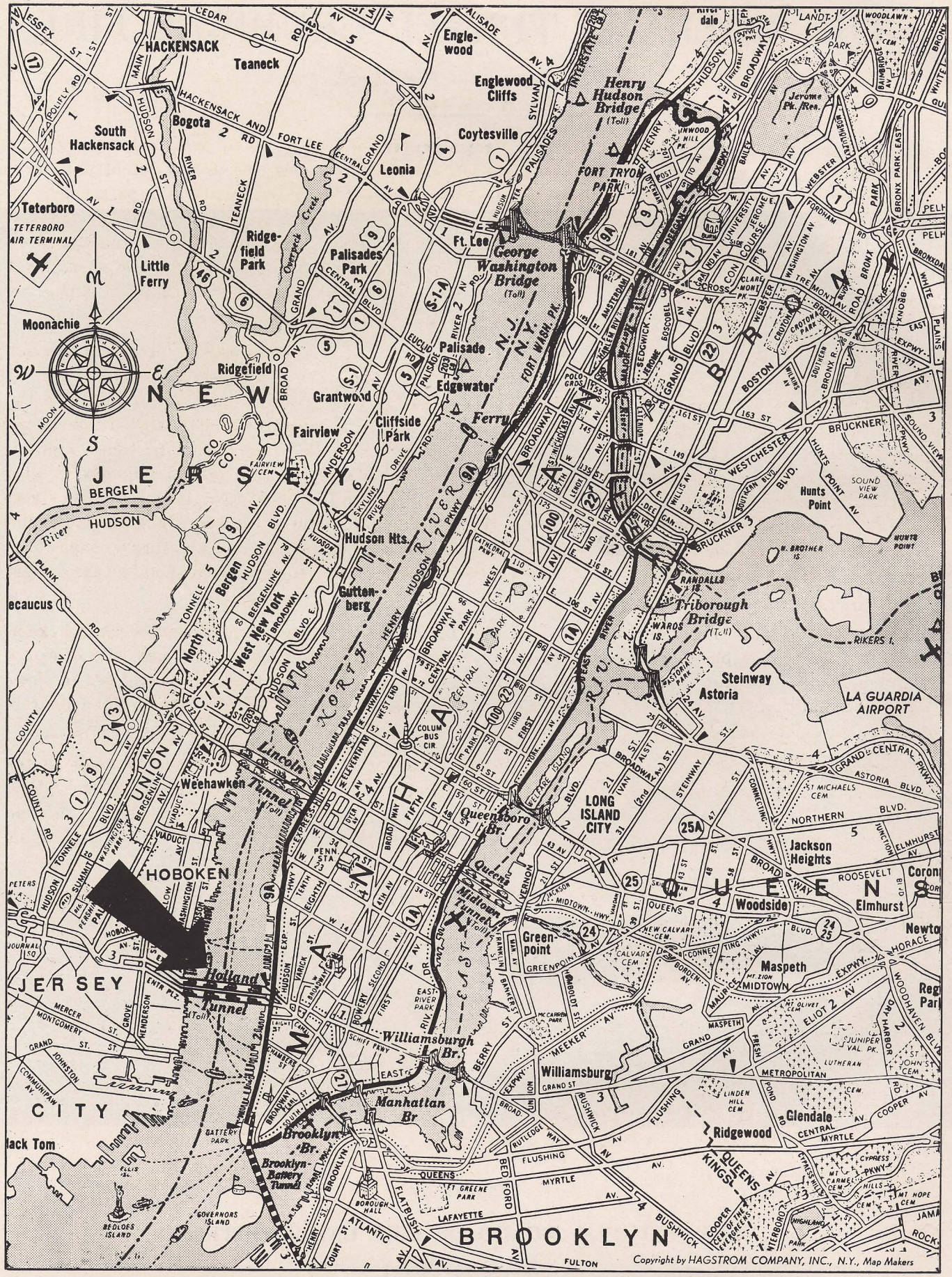

Principal Vehicular Arteries of Manhattan.

FOREWORD

The unusual chemical fire in the Holland Vehicular Tunnel may serve to point out, through the magnitude of the damage incurred from a single truckload of chemicals, the untold potential hazards which exist in our normal day-to-day highway transportation of dangerous materials, particularly in tunnels exposed to such shipments. A spot-check inspection made a few days after the fire brought out a shocking revelation. Out of some 6000 tunnel-bound trucks which were stopped, more than 100 were turned back for violating the existing safety regulations of the Port Authority. The serious extent of these violations is indicated by the fact that several trucks containing considerable quantities of dangerous chemicals were turned away during the first few weeks following the fire!

As we are awakened to these facts and the related difficulties of fighting serious fires in tunnels, it should be noted that the island of Manhattan is connected to its neighbors by no less than eight vehicular tubes and thirty-six railroad tunnels. This constitutes the greatest traffic tunnel concentration in the world. Though vehicular tunnels are somewhat less common than railroad tunnels, they are, however, being constructed at an increasing rate. The United States now has nearly forty vehicular tubes, approximating a total of 30 miles. The nationwide importance of this study of the Holland Tunnel fire, with respect to its standard and emergency operating procedures, its ventilation system and general construction, may be realized if consideration is given to the possible magnitude of the tragedy so narrowly and luckily averted. It is understood that the Interstate Commerce Commission is investigating possible violations of its packaging and loading requirements, but as this report goes to press, their findings are not yet available.

The effective manner in which this near-catastrophic incident was brought under quick control exemplifies the value of pre-planning and preparedness for emergencies, and argues for the necessity of establishing a complete disaster operations plan, gearing up all vital agencies with the police and fire services. It is hoped that tunnel authorities and fire and police chiefs throughout the country may benefit from this report. The safety and welfare of the general public warrants the earnest interest of all concerned.

Acknowledgment of valuable cooperation in the investigation of this fire is hereby made to the various officers and personnel of the Fire and Police Departments of Jersey City and New York. Particular appreciation is expressed to the officials of the Port of New York Authority for the information given regarding the construction of the tunnel and for making available various charts and photographic records reproduced herein.

Data collected for this report were obtained by Arthur Spiegelman, Senior Research Engineer; Robert C. Dean and Laurence M. Ford, Research Engineers, National Board of Fire Underwriters. The technical review and advices of Calvin G. Lauber, Assistant Chief Engineer, are also duly acknowledged.

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SUMMARY

A trailer-truck loaded with 80 drums of carbon disulfide burned in the New Jersey end of the south tube of the Holland Tunnel on the morning of May 13, 1949. This chemical fire in the close confines of the tunnel destroyed or damaged many trucks. The inner wall surfaces and ceiling slabs of the tunnel were demolished for a distance of 600 feet by the tremendous heat that was generated.

The phrase "Death Takes a Holiday" was brought to mind when the final count revealed no fatalities among the sixty-six injured persons. Because of an unusually fortunate set of circumstances, no passenger cars or transport buses were trapped in the immediate vicinity of the fire. The well-organized emergency plan of the tunnel authorities played an important part in averting a major disaster.

The carbon disulfide truck entered the tunnel in violation of Port Authority* regulations with regard to the quantity of chemical carried and the type of containers utilized, and allegedly lacked the DANGEROUS placards required by the Interstate Commerce Commission.

The fire was very difficult to extinguish due to copious fumes and close quarters, and required the combined efforts of the New York and Jersey City fire departments. Many hours were needed by the clean-up crews to remove the fused remains of the trucks. Hundreds of tons of rubble and debris were taken from the tube before it was opened to traffic, approximately two and one-half days after the incident.

The structural damage to the tunnel has been estimated at $600,000; this does not include the toll losses due to the interruption of business. Damage to trucks and their cargoes, along with destruction of telephone and telegraph cables will probably bring the total close to $1,000,000.

Suggested preventive measures include the utilization of the recommendations of the National Fire Protection Association's Committee on Truck Transportation. Other supplementary recommendations cover a safe routing plan, review of packaging and loading practices, and studies of sprinkler protection for tunnels. More intensive application of existing codes and local supplementary regulations through frequent "spot checks," with heavier penalties for violations, is also recommended for consideration.

* The Port of New York Authority is a self-supporting public corporate agency of the States of New York and New Jersey; created in 1921 to deal with planning and development of terminal and transportation facilities and to improve and protect the commerce of the New York-New Jersey Port District.

THE HAZARD PROBLEM OF TRUCKING TRANSPORTATION

The Holland Tunnel fire typifies another of the modern hazards brought about through the development of highway trucking and the attendant open and extensive usage of our various vehicular arteries for the transportation of dangerous materials of commerce. The growing importance of the problem is apparent from the increased utilization of trucks and truck-tractors from 732,000 in 1935, to more than 6,500,000 in 1948. This latter figure is equivalent to about one-fifth the number of registered automobiles. Trucks account for an annual traffic record of nearly 66,000,000,000 vehicle-miles, or better than one-fifth of the 300,000,000,000 vehicle-miles accumulated by passenger cars. Total highway and street mileage within the United States amounts to over 4,620,000 miles.

Ten subaqueous tunnels, consisting of fourteen tubes having a combined length of more than fifteen miles, are located within the United States. Twin tube structures, handling a total of almost 50,000,000 vehicles per year, include New York City's Holland, Lincoln, Queens-Midtown, and Brooklyn-Battery tunnels; the last is nearing completion. Single tube tunnels include the Sumner Tunnel in Boston, the Posey Tunnel between Oakland and Alameda, California, the Bankhead Tunnel at Mobile, Alabama, and the international tunnel between Detroit and Windsor, Canada. Two other single tube tunnels, the Washburn Tunnel at Pasadena and the Spillmans Island Tunnel, are under construction near Houston, Texas. These six single tube structures are rated to carry 30,000,000 vehicles per year.

Twenty principal underground tunnels ranging in length from 1500 to 5700 feet pass through various hills and mountains of the United States. Consisting of twenty-five tubes of more than fifteen miles total length, they handle some 125,000,000 vehicles per year.

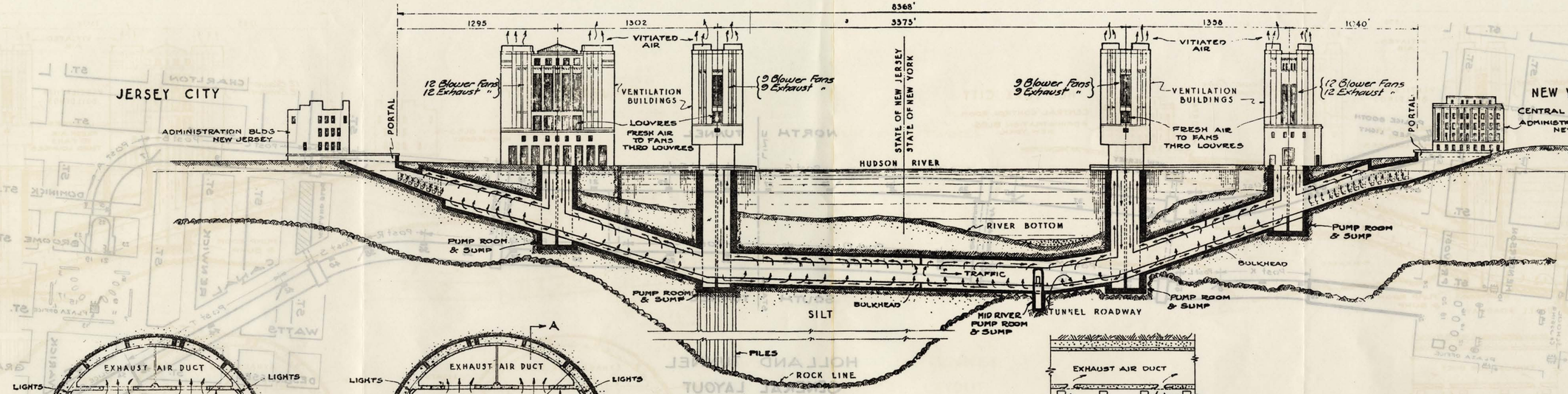
The safety of truck transportation is controlled by the Interstate Commerce Commission and some fifty various state departments, public utility and service commissions located throughout the United States. The Interstate Commerce Commission drafts the regulations for safe transportation within the limits of the United States of explosives and other dangerous articles, including flammable liquids, flammable solids, oxidizing materials, corrosive liquids, poisons, and compressed gases. Some 3000 interstate common carriers are affiliated with the American Trucking Association, Incorporated, which publishes and promulgates The Motor Carriers Explosives and Dangerous Articles Tariff No. 6 developed by the I. C. C. These regulations are further supplemented by local ordinances and port authority rules.

The growing problem of fire prevention and protection of the trucking industry has been recognized by the fire safety interests for some time. As early as 1935, the National Fire Protection Association viewed the potential danger with the following statement:

> "The movement of highly flammable solids, flammable volatile liquids, and other hazardous materials over our streets and highways, through cities, and thickly settled towns and villages, coupled with the greatly increased use of automobiles has gradually brought about a very undesirable and dangerous condition. At times not only are life and property on our highways seriously exposed, but our homes, hospitals, theaters, commercial and manufacturing establishments, and sometimes schools and churches may be greatly endangered."

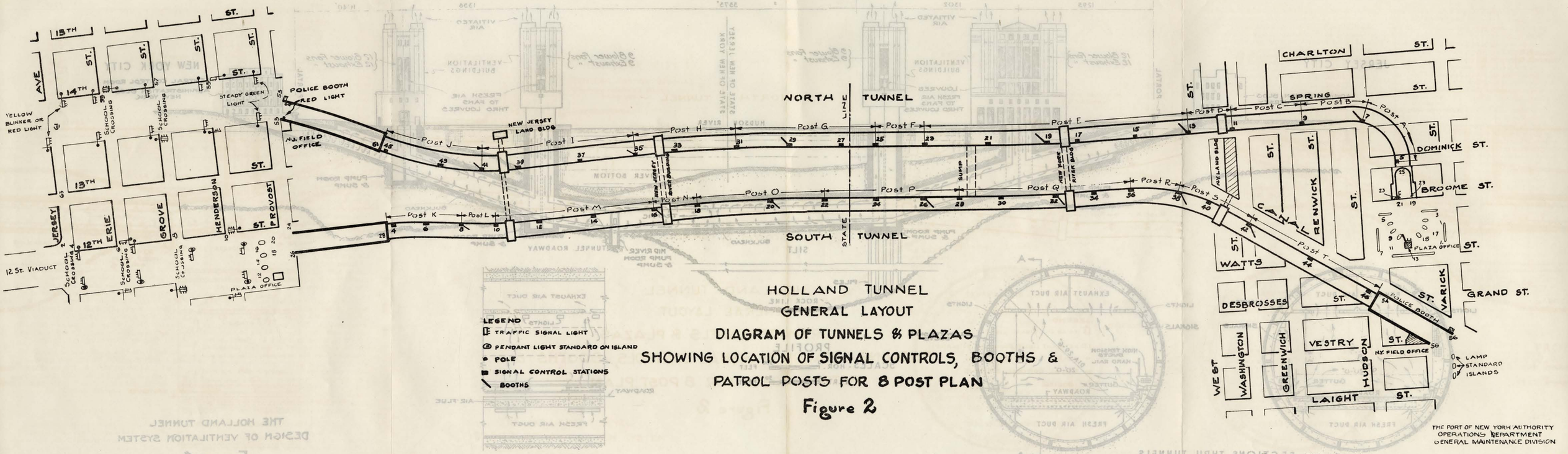
In response to the apparent seriousness of the situation, a technical committee on truck transportation was promptly organized to add to the efforts of governmental and state bodies and help bring about a more responsible degree of protection from every possible angle.

There exist today several hundred pages of rules and regulations, containing more than 300,000 words, and, in the opinion of most authorities, the amount of legislation is ample if proper enforcement is provided. There is a much greater need for the broadening of enforcing powers with provisions to treat serious violations as felonies, with heavier fines and stiffer imprisonment terms, rather than as ordinary misdemeanors.



THE HOLLAND TUNNEL
DESIGN OF VENTILATION SYSTEM

Figure 1



HOLLAND TUNNEL
GENERAL LAYOUT
DIAGRAM OF TUNNELS & PLAZAS SHOWING LOCATION OF SIGNAL CONTROLS, BOOTHS & PATROL POSTS FOR 8 POST PLAN

Figure 2

THE PORT OF NEW YORK AUTHORITY
OPERATIONS DEPARTMENT
GENERAL MAINTENANCE DIVISION

REVISED 5-27-48

GENERAL MAINTENANCE SUPERINTENDENT

GM-100

2, 1946, a trailer-truck loaded with chewing gum and shoe polish overturned and burned in the westbound tube. Loaded with 12 tons of merchandise, the truck caught fire near the Jersey City end of the tube at the height of the evening rush hour. Smoke filled much of the tunnel and the roadway soon was covered with a molten mass. More than 300 cars and trucks that were stopped behind the overturned truck were backed out at the New York end. Traffic was held up for four hours while the fire was extinguished, the truck removed, and the roadway cleared of debris.

On another occasion an auxiliary gasoline tank fell from a truck and was dragged several hundred feet before becoming separated from the vehicle. The fuel was spilled on the roadway, but no fire resulted. Traffic through the tunnel was halted while the gasoline was flushed into the sumps, located below the roadway, by hose streams. The sumps were filled and emptied three times before traffic was allowed to proceed. The sumps contain 4 booster pumps and 18 standard centrifugal pumps of 100 to 1000 G.P.M. capacity.

Tunnel Control and Emergency Operations

The control or "nerve center" of the tunnel operating system is centralized in the Supervisor's Room, remotely located in the New York Administration Building. This arrangement permits the Supervisor to obtain an over-all picture of any emergency within the tunnel and makes possible the swift handling of any traffic tie-ups or troubles. From this central point, the operation of the entire ventilation system can be directed, and by means of an elaborate system of tunnel telephones it is possible to communicate directly with the patrolmen stationed along the walkways. Traffic regulations for the tunnel provide for a maximum speed of 30 miles per hour and a required distance of 75 feet between vehicles, as indicated by signs and markers.

Four emergency trucks are provided, two for each tube. These combined fire-fighting and wrecktow units are located near the exit ramp of each tube. Two have a double-steering apparatus to permit operation in either direction within a tube, and are outfitted with hoists, ladders, hose, jacks, portable lights, axes, tarpaulins, and include a 200-gallon water tank, dry foam powder, and vaporizing liquid extinguishers. About 200 men, operating in shifts, constitute the staff for combination police-fire duty and toll collection.

The Port Authority has standard operating procedures to meet emergency conditions within the tunnels. In case of vehicular breakdown or other accident within a tube, the nearest patrolman or tunnel officer transmits a trouble signal to the control room, which he then calls by telephone to give details. After receiving a trouble signal, operators in the control room turn the signal lights to amber or "caution" and alert the tunnel emergency crews. If telephonic communication with the patrolmen in the tunnel shows the need for an emergency crew, it is dispatched into the tube.

In case of fire within the tunnel the patrolman nearest the scene pushes a fire alarm button. This automatically turns all lights red between the tunnel entrance and the point from which the alarm was received. Beyond this location lights turn to amber, allowing vehicles to proceed with caution from the tunnel. Traffic is directed into the right-hand (slow) lane by the patrolmen. A tunnel emergency vehicle immediately enters the tube against the flow of traffic and proceeds to the scene of the fire to aid in its extinguishment and to remove any vehicles involved. If the fire is of a serious nature those vehicles which are blocked between the fire and the entrance are backed from the tunnel by patrolmen and emergency crew members.

To assist in the confinement of fire and smoke to the ventilating section in which it originates, an emergency ventilation procedure is utilized by the Port Authority. By shutting off the blower fans (with exhaust units operating) in the section involved and the exhaust fans (with blower units operating) in the adjacent sections, a longitudinal flow of air is directed toward the fire area from each side, thus minimizing the spread of smoke and heat to other sections.

DETAILS OF THE SOUTH TUBE FIRE

A chemical fire in a large trailer-truck loaded with 48,536 pounds of highly flammable and volatile carbon disulfide, contained in 80 fifty-five gallon drums (reported to be I. C. C. Specification 17E and 17C types), severely damaged the south tube of the Holland Tunnel. The vehicle hauling this load consisted of a fully enclosed trailer body with tandem dual rear wheels, pulled by a truck-tractor. This truck, which had entered the Jersey City side of the tunnel on Friday, May 13th, at about 8:45 A.M., in violation of Port Authority regulations and which had allegedly been traveling without "Dangerous" placards in violation of I. C. C. regulations, set off a series of fires and blasts in the tunnel. The devastation was such that the inner walls and ceiling were destroyed for a distance of 600 feet and ten large trucks were completely burned. Thirteen other trucks were partially damaged.

It was only by virtue of the fortunate circumstances that there were no fatalities among the sixty-six injured persons. Twenty-seven of these required treatment in New York and Jersey City hospitals. None of the victims were in serious condition at the time of this writing. Authorities considered it "miraculous" that many of the passenger cars and buses in the tunnel at the time were not involved in the devastated area. Three bus loads of children were stopped at the entrance of the tunnel when the fire occurred.

The ten trucks involved in the fire during the early stages were divided into two groups (See Figure 3). The five forward trucks, including the carbon disulfide unit, were approximately 2900 ft. from the New Jersey entrance. The remaining five trucks were 350 ft. to the rear. The forward group in the right lane consisted of three trucks containing meat, bottled bleach, and paint supplies, and a fourth vehicle which was empty. The carbon disulfide truck rolled to a stop in the left lane. The rear group consisted of five trucks in the right lane. These contained wax, clams, groceries, tomato juice, paper rolls, and wooden barrels. The meat truck was removed from the tunnel about 45 minutes after the fire started, but the others were immovable by the time the fire departments arrived.

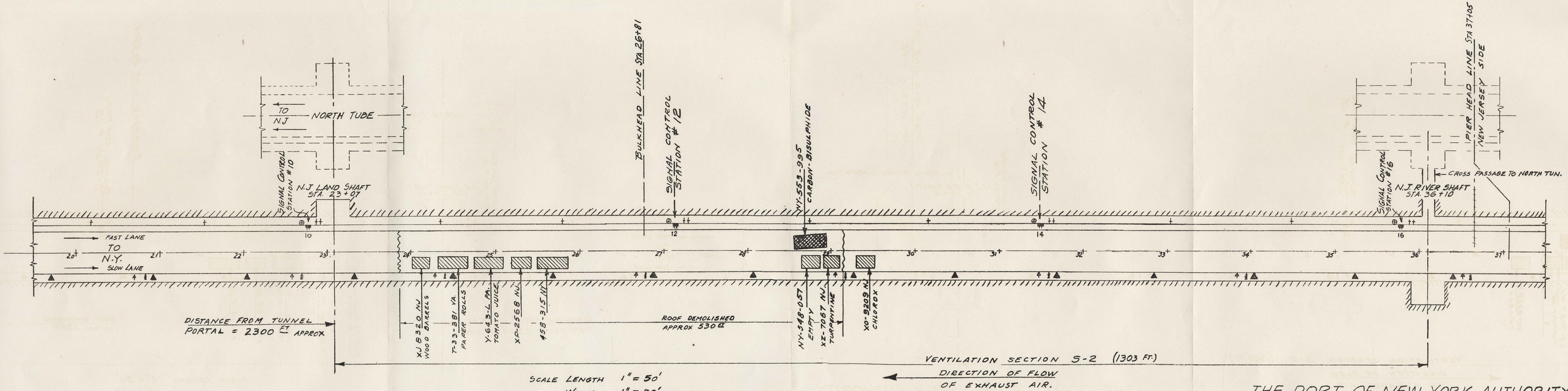
The carbon disulfide was manufactured by the J. T. Baker Company at their Taylor Chemical Division, Cascade Mills, New York, and it was consigned for export to the European Chemical Company in care of the Farrell Steamship Lines, Pier 2, 33rd Street, Brooklyn, New York. This material was to be shipped in the *S.S. African Glade* to South Africa. The trailer carrying the shipment was delivered to the Jersey City terminal of the Boyce Motor Lines and was laid over awaiting delivery on Thursday night. Another driver picked up the trailer at about 8:20 A.M. on Friday and started to make his delivery by way of the Holland Tunnel. The commercial traffic was particularly heavy that morning and moving slowly into the tunnel.

Reports from various sources on the conditions and time of the occurrence of the fire are somewhat varied and confused. The most credible sequence of events is as follows:

At 8:48 A.M. a tunnel officer who was assigned to Post M (See Figure 2) transmitted an amber (trouble, breakdown, etc.) signal to the control room, where the supervisor recorded it and switched the tunnel traffic lights to amber, slowing traffic in the south tube. The original signal had been sent by the patrolling officer because he saw a truck apparently stalled about 100 ft. west of his position near Station 16. As he ran toward the truck, a loud blast occurred in its vicinity, and he was met by two men running eastward. He guided these men through the connecting passageway to the adjacent north tube. On returning to the south tube, he found that a tunnel officer had collapsed, and he immediately assisted him to the north tube.

Meanwhile, the tunnel emergency crew was standing by in the garage on the New York side, according to customary amber signal procedure. The sergeant of this crew saw a man stagger into the New York office and gasp that he was gassed, and then collapse. He was identified as a driver of one of the trucks and later was removed to a hospital for treatment. He had driven his truck out of the tube by order of a tunnel officer.

At 8:56, a fire alarm was received from Station 26, east of the fire, on the New York side, and the emergency crew, consisting of three men with a jeep and a tractor, immediately entered the south tube. This fire alarm was transmitted by the tunnel officer at Post P. He had noticed the presence of dense fumes and the absence of traffic, and was attempting to report to the Supervisor when another tunnel officer from Post Q (still farther east) joined him. They noticed smoke to the west and transmitted the fire alarm. After this they ran toward the scene. The fire alarm signal automatically activated a well planned procedure in the tunnel. All signal lights behind Station 26 became red, halting incoming traffic. The signals ahead of Station 26 flashed amber lights, indicating to traffic to proceed slowly in the right or slow lane, and



SYMBOLS

- ▲ HOSE OUTLETS
- SAND
- 1 FIRE EXTINGUISHER
- 5 FIRE EXTINGUISHERS
- ⊕ TELEPHONE
- FIRE ALARM & SIGNAL CONTROL
- 12 ← SIGNAL CONTROL STATION NUMBER

THE PORT OF NEW YORK AUTHORITY
DEPARTMENT OF OPERATIONS
HOLLAND TUNNEL
SOUTH TUNNEL (IN PART)

Figure 3

FIG. 4. View of Jersey entrance to south tube during the fire with smoke pouring from land ventilating shaft. Note river shaft in background to the right.

leaving the left lane free for the entrance of emergency equipment.

At about this time the Port Authority emergency equipment had reached the scene of the fire, and had commenced fighting it with a fog nozzle on a line connected to a standpipe outlet 75 ft. east of the first blazing truck.

The first call reached the New York Fire Department at 9:12 A.M. This call was from the New York Police Department, in which it was reported that "a drum of chemicals had fallen from a truck . . . and fumes were filling the tube." Rescue Co. No. 1 and the Chief of the 5th Battalion responded at 9:13. This Battalion Chief, on arriving at the scene, immediately called the tunnel PBX operator to ask the New York Fire Department for a full first alarm assignment.

The Jersey City Fire Department received a telephoned notice at 9:05 A.M. that "a truck was afire at the eastbound side of the Holland Tunnel." A Battalion Chief, rescue unit, pumper and truck were immediately dispatched. The Chief of the Department, soon after his arrival on the scene, directed the transmission of a second alarm. The north tube was closed to traffic at 9:20 A.M.

Firemen entering the eastbound tube from the New Jersey entrance worked their way through the two lanes of parked vehicles formed by over

FIG. 5. View from New York side of trucks which carried carbon disulfide (right) and paint supplies (left). See FIG. 3. for orientation of truck positions.

100 automobiles, buses and trucks. It was necessary to carry the 2½" hose lines into the tunnel and the standpipe facilities found inside provided the supply of water. Progress was slow due to the heavy fumes. It was a step by step procedure until the nearest truck fires were extinguished. Tunnel emergency crews were removing the vehicles to the rear of the burning trucks during this action. By 10:15 A.M. all vehicles not on fire had been removed from the Jersey entrance, simplifying fire fighting at that end.

In the meantime the fire fighting from the New York side was even more difficult as this was closer to the truck carrying the carbon disulfide. The problem of parked vehicles was not present, however, as all of the traffic in front of the trucks involved had proceeded directly out of the tube. It was possible to drive the fire equipment close to the scene of the fire. The situation was complicated at this end by the release of small amounts of chlorine fumes from the truck carrying the bottled bleach solution and the bursting of carbon disulfide drums releasing the toxic fumes of the chemical and its decomposition products. Most of the New York firemen who responded to the first alarm were treated for smoke and gas inhalation by the police and fire emergency crews and the medical personnel attached to several hospital ambulances. Breathing at the air inlets in the tunnel was more comfortable, and several firemen who had been affected made use of this source of fresh air by getting as close to the inlets as possible. Gas masks of the self-contained breathing type, as well as the all-purpose canister type, were used for approximately the first hour of the operation. It is estimated that over 100 self-contained breathing apparatus were available to the firemen. It was noted that this was the first time in the history of the New York Fire Department that four rescue companies were required at one fire.

Visibility was cut down to a minimum by the concentration of smoke when the firemen first entered the south tube. A pall of uncertainty hung over the entire operation. Disruption of both lighting circuits caused the tunnel lights to go out and portable emergency units had to be brought in. The fact that the tunnel ventilating system continued to function so efficiently is believed responsible for saving many lives. When reports reached fire headquarters that considerable damage had been

FIG. 6. Scene at rear end of chemical truck. Carbon disulfide drums being identified by National Board of Fire Underwriters engineers and a Port Authority investigator. Note damage to exhaust air duct in ceiling and spalled cement lining exposing structural rings of the tube shell.

done to the ceiling and air-exhaust duct of the involved tube, two fireboats were directed to station themselves in the Hudson River above the tunnel to watch for bubbles and evidence of leaks.

Some indication of the intensity of the fire was its rapid and unusual spread from the carbon disulfide truck through 350 feet of empty tube to the second group of trucks. The wall surfaces and ceiling slabs of this entire section were demolished and large sections of concrete were suspended precariously from above by the steel wire reinforcements. The roadbed was completely covered with broken concrete and tile several inches deep. The heavy debris and the run-off water made the footing treacherous.

Severe heat in the exhaust system caused three exhaust fans in the New Jersey Land Ventilating Building to be damaged. Of these, two fans were out of service at about 10:00 A.M.; one was kept in service. This involved half of the six fans which ventilated Section S-2 (See Figure 3). The three blower fans continued to operate. Port Authority maintenance personnel cooled the fans by the use of water from hose lines. The intense heat in the fan room caused the interior painted surface to blister and scale off.

The fire caused other damage such as the disruption of telephone, telegraph, radio and television connections between New York and points south and west of the Hudson. Some 2600 long distance message circuits depending on five cables laid through the tunnel were reported to have been put out of service. A 900-pair cable serving as a trunking facility from central phone offices in northern New Jersey to main offices in New York was affected and the new coaxial television cables were broken. This was one of the worst tieups in the history of the American Telephone and Telegraph Company.

After extinguishing the fire, the combined emergency crews worked for over 16 hours before they were able to remove the charred remains of the four trucks in the forward position. These trucks had twisted and sagged into immobile units by the tremendous amount of heat. On the Jersey side of the tunnel a similar period of time elapsed

FIG. 7. View of second group of trucks destroyed by fire at a distance of 350 feet to the rear of the carbon disulfide truck. Note patrol walkway for tunnel officers (right) and location of fresh air inlets underneath.

before the five trucks could be taken from the tunnel. These trucks were completely destroyed and were removed with the greatest of difficulty. One of the trucks contained large rolls of newsprint which continued to smolder long after it had been removed.

In the course of the removal operations, at approximately 6:50 P.M., spilled material in the vicinity of the carbon disulfide and turpentine trucks reflashed, again causing a considerable amount of smoke and fumes which affected Port Authority personnel and clean-up crews at work in the tube. Firemen stood by with hose lines, but the burning material, which ignited in gutters and drains causing a series of muffled explosions, was extinguished with more than twenty 5-gallon foam extinguishers. Following this, the fire department set up a foam hopper and covered the area with heavy foam, using over 30 cans of powder.

Over 650 tons of debris were taken from the tunnel by a large emergency crew which worked continuously at the job. The overhanging steel webbing and rod reinforcements and the loose sections of concrete were removed to make transit safe. The roadbed which at first appeared badly damaged by the fire was found to be in surprisingly good condition. The granite block road, apparently protected by the debris, had withstood the shock and intense heat very well. The main structure of the tunnel was not damaged and it was estimated that repairs to the inner structure, made during intermittent shutdown periods from 8:00 P.M. to 6:00 A.M., would take at least two months. The south tube was officially reopened to traffic 56 hours after the fire started. The westbound or north tube was opened to two-way emergency operation at 2:05 P.M., the day of the fire. The A. T. & T. telephone circuits were 50 per cent restored by nightfall.

Wartime civil defense gas masks appeared as emergency equipment at the scene of the fire. They were not Port Authority equipment. These were intended for use against relatively moderate concentration of chemical warfare agents, and are totally ineffective against carbon monoxide, a gas

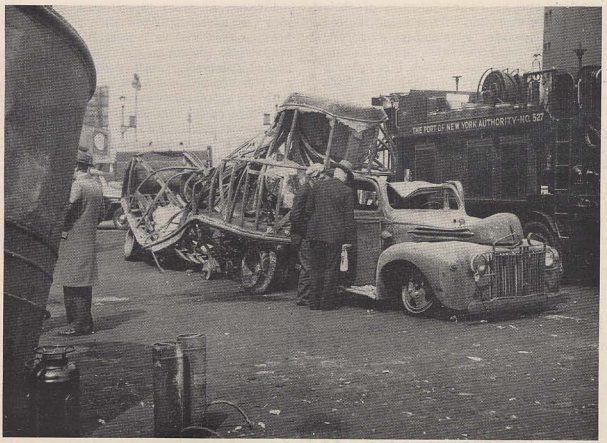


FIG. 8. Heat-distorted wreckage typical of fire damage sustained by trucks. View of emergency tow and fire truck employed at Holland Tunnel.

commonly present at all fires. Considering the potential presence of heavy concentrations of such toxic gases as ammonia, chlorine, sulfur dioxide, and hydrogen sulfide, these protective devices would appear useless, if not dangerous.

Jeep reconnaissance cars and "walkie-talkie" radio-telephone equipment played a role in providing important communication facilities with the working parties and supporting crews outside the tunnel.

REPORTS ON EMERGENCY OPERATIONS

Operations of the Port Authority Emergency Crew

On receiving the alarm of fire from Signal Control Station 26, the emergency crew from the New York end entered the tunnel with two men on a tractor and one on a jeep. Near Station 26 they stopped to pick up two tunnel patrolmen, then proceeded around the bend until the fire was seen. The crew utilized their all-service gas masks and advanced through heavy smoke and fumes to connect a 1½" hose equipped with spray nozzle to the standpipe outlet about 75 ft. from the first burning truck. As they approached the scene they saw a large ball of fire in the tube ahead.

While some emergency crew members were fighting the fire, others assisted two tunnel patrolmen who, unequipped with gas masks, were overcome by the smoke. The fires in the first and second trucks containing the meat and bleach solutions were knocked down, and the men were advancing on the third truck when they noted flaming liquid running down the gutters on both sides of the tunnel. The sergeant in charge of the emergency crew then went to telephone for more help. At about this time the first New York Fire Department rescue company arrived on the scene and took over operation of the hose line.

Three of the Port Authority emergency crew connected the tractor to the first truck and towed it out of the tunnel. They then re-entered the tunnel to remove the second truck; but, affected

by exhaustion and by fumes in spite of their masks, they were overcome. After being revived with inhalators operated by members of a New York Police Department emergency squad, the tunnel emergency crew was hospitalized. Fire fighting and emergency control operations at the New York end were continued by the New York City Fire Department and Police Department.

At the New Jersey end of the tube the scene was quite different. Many cars, trucks, and buses had passed the toll booths between the time of the amber and red lights. Several of the supervisory personnel were in the tunnel at the time the incident occurred. They were instrumental in immediately sizing up the situation and directing patrons to leave the vehicles and go to the entrance. Emergency crews, tunnel police and other personnel, under the handicaps of heavy smoke and fumes, aided in removal of approximately 125 cars and trucks which were stopped in the tunnel. After the tube was cleared, the fire fighting equipment was moved up and the fire at the Jersey end was gradually brought under control.

The work of the Port Authority emergency crews proceeded long after the last fire was extinguished. They assisted in removing the remains of the fire-damaged vehicles and in restoring some semblance of order to the chaotic appearance of the involved area. Nineteen men were treated for smoke and fume poisoning and twenty-one others received minor medical treatment.

Operations of Jersey City Fire Department

At 9:05 A.M. the Jersey City Fire Department received a telephone call stating that a truck was on fire at the eastbound side of the Holland Tunnel. An engine company, truck company, the rescue company, and a Battalion Chief were immediately dispatched to the scene. The Chief of the Fire Department also responded as soon as he was notified of the fire.

After entering about twenty feet into the tunnel, the Chief encountered strong fumes of sulfur dioxide. Withdrawing from the tunnel, he immediately ordered the transmission of a second alarm. All oxygen masks were ordered to be taken to the scene by fire department shop trucks and the services of a police emergency squad were requested.

Two firemen equipped with masks entered the tunnel and made their way to the scene of the fire. On returning to the entrance they reported that a chemical truck was on fire about 1500 feet inside, and that there had been a series of explosions.

Firemen, all provided with masks, were divided into teams and equipped with rolled lengths of hose, nozzles, and various tools. They then proceeded into the tunnel between the two lanes of stalled automobiles and encountered the first of a series of burning trucks. A 2½" line equipped with a 1¼" nozzle was connected to the nearest standpipe outlet and the fire in the nearest two trucks was partially extinguished. The line was then advanced about two hundred feet and extinguishing operations continued. By the use of a wye two lines were taken from a single standpipe connection. The advance of the fire department was quite rapid.

About forty-five minutes after the arrival of the fire department and after the ventilation of the tunnel had been accelerated, the firemen discovered that they could work without masks, thus increasing the efficiency of all operations.

Two hours after the Jersey City Fire Department was called, all undamaged vehicles had been removed. Two 1250 GPM pumpers were then driven into the tube, laying hose as they progressed. These pumpers were connected to relay water to the fire from a third pumper stationed at a hydrant near the tunnel entrance. This was an emergency measure in the event of failure of the tunnel standpipe system.

The New York Fire Department was met on reaching the site of the original fire. Extinguishing and overhauling operations were continued for some time; the Jersey City Fire Department did not leave the scene until 12:52 A.M., Saturday, more than fifteen hours after receiving the first call.

Response by the Jersey City Fire Department included six pumpers, three trucks, one rescue unit, one portable lighting truck, and six chief officers. Sixteen self-contained oxygen masks were available for use. Ten firemen were hospitalized for smoke poisoning and two were treated for head injuries.

Operations of New York Fire Department

At 9:12 A.M. the dispatcher in Manhattan Fire Alarm Headquarters received a call from the New York City Police Department stating that a drum of chemicals had fallen from a truck in the Holland Tunnel and fumes were filling the tube. Rescue Co. 1 and the Chief of the 5th Battalion were dispatched to West and Spring Streets, near the entrance to the westbound tunnel, at 9:13.

Accompanied by members of the Rescue Company, the Battalion Chief proceeded into the westbound tunnel until nearly opposite the point at which the accident had occurred. They then crossed to the eastbound tube through an emergency exit and discovered a number of trucks on fire. Heat was extremely severe and smoke and gas concentrations very heavy. The Chief immediately called the tunnel switchboard operator to ask the New York Fire Department for a full first alarm assignment. This alarm was transmitted at 9:30 and brought four engine companies, two ladder truck companies, and a water tower. Meanwhile, members of Rescue Co. 1 wearing self-contained breathing apparatus attempted to hold the fire in check with the 1½" hose that had been stretched from the tunnel standpipe by members of the tunnel emergency crew. No hose was available in the hose cabinets of the tunnel, but the tunnel emergency wagon had brought hose to the scene of the fire.

Other members of the rescue company conducted a search of the burning trucks for trapped occupants and helped three persons to safety.

On arrival at the tunnel at approximately 9:32, the first due engine company drove into the eastbound tunnel within 300 feet of the fire, connected the pump to the tunnel standpipe system, and stretched two 2½" lines from the pump to the fire. The other engine companies connected lines into the standpipe siamese at the New York end in order to build up the pressure, then entered the tunnel to place other lines in operation on the fire. In addition to the two lines operating from the pumper within the tunnel, three lines were connected from the tunnel standpipe system. Lines were also operated for a time from a foam generator set up by the rescue company.

Members of the truck companies assisted in the search of vehicles and in placing and advancing the hose lines. In order to remove the heat and smoke the tunnel ventilating system was sped up to the limit of its capacity.

Because of the difficulties under which operations were being carried out, special calls were sent out for three remaining fire department rescue companies and for the two department ambulances. One rescue company was sent through the midtown Lincoln Tunnel to the New Jersey end of the Holland Tunnel where it assisted in advancing hose lines and searching vehicles for trapped occupants. One department ambulance also was sent to assist at the Jersey end.

The heat and fumes accounted for many men being overcome. Twenty-nine members of the companies responding on the first alarm, as well as nine chief officers and aides, were treated for smoke inhalation by the rescue companies, the department ambulance crews, and by those from several city hospitals.

Primarily to provide additional manpower a second alarm was transmitted at 11:19, bringing four engine companies and one truck company to the scene. A special call for forty additional men was also made.

By one o'clock the fire was practically out, although the nature of the wreckage made complete extinguishment difficult. That night, while the wreckage was being cleared away, fire broke out in the debris. A special call was transmitted for the smoke ejector and foam truck. A foam generator was set up and foam discharged on the flammable liquids until the fire was completely extinguished.

Operations of Other Emergency Services

Truck drivers fleeing from the fire reported to a New York City patrolman at the exit of the tunnel that they had been gassed. Upon being notified of this incident the police dispatcher sent two police emergency squads, two patrol cars, and an ambulance to the tunnel at 8:59 A.M. Fifteen minutes later another ambulance was sent to the scene and the Jersey City Police Department was requested to send additional aid.

When the first call for help came to the Jersey City Fire Department at 9:05 A.M., ambulances from the Jersey City Medical Center responded to the west end of the tunnel. At the request of the Chief of the Jersey City Fire Department, the Jersey City Police Emergency Squad went to the scene a few minutes later.

Four emergency trucks equipped with inhalators were requested from the Consolidated Edison Company of New York. Shortly afterward a third New York police emergency squad was ordered to the tunnel.

As the number of persons overcome and requiring assistance increased, the New York Police Department called for the Bellevue Hospital disaster unit. Three additional ambulances, six doctors, and several nurses were sent to the area. At 10:23 three more New York police emergency squads were dispatched to aid operations. Additional ambulances were later called from four downtown New York hospitals.

CARBON DISULFIDE PROPERTIES AND HANDLING SAFEGUARDS

Chemical and Physical Data

Carbon disulfide (CS_2) is highly volatile, easily ignitable, and dangerously flammable over a broad range of vapor concentration, and is a foul smelling liquid having the following characteristics:

Flash Point	−22° F.
Flammable Limits in Air	1 to 50%
Ignition Temperature	212° to 223° F.
Vapor Density	2.62 (air = 1.00)
Boiling Point	115°F.
Color	Colorless or yellow
Specific Gravity	1.29 (water = 1.00)
Solubility in Water	0.014 parts/100 by wt. at 122°F.

Uses

Carbon disulfide is used in the rubber industry, the manufacture of explosives, in the viscose process of rayon manufacture, as a fumigant, and as a solvent in many chemical processes.

Fire Hazard

Because of its rapid rate of volatility, low flash point, low ignition temperature, and wide flammable limits, carbon disulfide is one of the most dangerous of common chemicals. The Underwriters' Laboratories, in its numerical classification of flammable liquids, gives carbon disulfide a rating of 110+, while gasoline and ethyl ether are 95-100, kerosene is 40, and carbon tetrachloride is 0. Such sources of heat as a steam pipe, a hot electric light bulb, or a metal roof heated by sunlight can be sufficient to cause ignition of the vapors. Since the vapors are heavier than air they may travel a considerable distance to a source of ignition and flash back.

Concentrations of the vapor most likely to explode with maximum violence are from 4% to 8%. Pressures produced by such explosions have been shown to range from 25 to 125 pounds per square inch above atmospheric.

Toxic Hazards

Carbon disulfide is comparatively toxic. Inhalation of high concentrations of the vapor has a narcotic effect; respiratory failure and death may result. Prolonged exposure to lower concentration may cause damage to the nervous system. Headache, vertigo, muscular weakness and tremors, blindness, changes in temperament, and even acute mania may result. Concentrations as low as 0.10% to 0.38% are dangerous after exposure of 30 minutes to one hour.

Products of combustion of carbon disulfide are carbon dioxide, carbon monoxide, and sulfur dioxide. The latter is an extremely irritant gas which forms corrosive sulfurous acid with normal moisture of the atmosphere; as little as 0.002% can cause immediate irritation to the eyes and cause coughing. Concentrations of 0.040% to 0.050% are dangerous for even short exposure.

Storage and Handling Requirements

Carbon disulfide in storage should be isolated and the containers safeguarded against mechanical injury and metallic blows. Storage should be in an unheated compartment and away from sunlight, hot pipes, electric lighting fixtures, and other possible sources of ignition.

Storage tanks should be constructed over concrete basins containing water and the carbon disulfide in the containers should be blanketed with water or inert gas at all times.

Carbon disulfide should never be transferred by means of air pressure, but should be handled by pump, or by displacement with inert gas, or water. A wooden, not metallic, measuring stick should be used for gauging contents of storage tanks or tank cars in order to avoid a spark hazard. Tank cars and other containers should be well grounded when being loaded or unloaded. Secure stowage of containers in transit is an essential safeguard.

Disposal of carbon disulfide should be by burning under proper conditions in a safe location, away from populous areas, rather than by dumping on the ground. Disposal into sewers should not be allowed.

Additional information for safe handling and use of carbon disulfide is available in the very complete Chemical Safety Data Sheet SD-12 (1948) prepared and distributed by the Manufacturing Chemists' Association of the United States, Washington, D. C.

Shipping Regulations

Motor transportation of dangerous chemicals, such as carbon disulfide, by common carriers engaged in interstate commerce is regulated by the Interstate Commerce Commission. State, municipal, or other local authorities may establish regulations governing motor traffic within their jurisdiction. These regulations, affecting intrastate and interstate traffic passing through any locality, may

be more or less stringent than those of the Interstate Commerce Commission.

Trucks passing through the Holland Tunnel fall within the jurisdiction of both the Interstate Commerce Commission and the Port of New York Authority. Regulations of these agencies pertaining to transportation of carbon disulfide are as follows:

Interstate Commerce Commission—"Transportation of Explosives and Other Dangerous Articles by Motor, Rail and Water." (See reprint by American Trucking Association, issued March 30, 1949, and effective May 6, 1949.)

P. 6—Secs. 1-4—**Carbon bisulfide (disulfide)**

Classed as—**Inflammable Liquid**

Exemption and packing—**No Exemption, 106**

Label required if not exempt—**Red**

Maximum Quantity in one outside container by rail express—**Not Accepted**

P. 24—Sec. 823 (a)—Marking on Motor Vehicles

Marking on motor vehicles and trailers other than tank motor vehicles. Every motor vehicle transporting any quantity of dangerous explosives, Class A, poison gas, Class A or radioactive material, Poison Class D requiring red radioactive materials label, and every motor vehicle transporting 2500 pounds or more of explosives; Class B, inflammable liquids, corrosive liquids, compressed gas and tear gas, or 5000 pounds or more of two or more articles of these groups shall be marked or placarded on each side and rear with a placard or lettering in letters not less than three inches high on a contrasting background as follows:

Explosives, Class A .	EXPLOSIVE
Explosives, Class B .	DANGEROUS
Inflammable Liquid .	DANGEROUS
Corrosive Liquid . .	DANGEROUS
Compressed Gas . .	COMPRESSED GAS
Poison Gas, Class A .	POISON GAS
Tear Gas	DANGEROUS
Dangerous, Class D Poison	DANGEROUS—RADIOACTIVE MATERIAL

P. 49—Sec. 106

(a) **Carbon bisulfide (disulfide)** must be packed in specification containers as follows:

(b) Spec. 11A or 11B—Wooden barrels or kegs with glass, earthenware, or metal inside containers not over five pints capacity each.

(c) Spec. 12B—Fibreboard boxes with inside containers which must be: Glass, earthenware, not over one pint each, or metal cans, not over one quart each; outside containers not to exceed 65 pounds gross weight.

(d) Spec. 15A, 15B, 15C, 16A, or 19A—Wooden boxes with inside metal containers, Spec. 2A; or with inside glass or earthenware containers not over five pints capacity each.

(e) Spec. 17E—Metal drums (single-trip) not over *five gallons* capacity each, with openings not exceeding 2.3 inches in diameter.

(f) Spec. 5, 5A, or 17C (single-trip)—Metal barrels or drums not over *55 gallons* capacity each with openings not exceeding 2.3 inches in diameter.

(h) **Carbon bisulfide (disulfide)** must not be offered for transportation by **rail express.**

(i) Spec. MC300, MC301, MC302, or MC303 tank motor vehicles.

Note: Drums meeting 17E and 17C specifications are made in several sizes. The use of 17E—*55 gallon* drums for carbon disulphide constitutes a violation of I. C. C. regulations. Some of the major differences between the 17C and 17E containers are found in the specification of the Motor Carrier's Explosives and Dangerous Articles Tariff No. 6, and are herewith drawn to attention:

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Spec. 17C—7. **parts and dimensions**—as follows: 55 gallons—minimum steel thickness in the black (Gage, U. S. Standard) body sheet 16, head sheet 16 (0.0625")

Spec. 17E—7. **parts and dimensions**—as follows: 55 gallons—minimum steel thickness in the black (Gage, U. S. Standard) body sheet 18, head sheet 18 (0.0500")

Spec. 17C

13 (b). Hydrostatic pressure test of *40 pounds per square inch sustained for 5 minutes.*

Spec. 17E

13 (b). Hydrostatic pressure test of *15 pounds per square inch sustained for 5 minutes.*

Spec. 17C

14. **Leakage Test.** Each container shall be tested with seams under water or covered with soapsuds or heavy oil, by interior air pressure of at least *15 pounds per square inch.* Equally efficient means of testing are authorized upon demonstration and proof of satisfactory tests to representatives of the Bureau

of Explosives. Leakers shall be rejected or repaired and retested. Removable head containers not required to be tested with heads in place except that samples taken at random and closed as for use, of each type and size must be tested at start of production and repeated every four months. Samples so taken must be retained until further tests are made.

Spec. 17E

14. **Leakage Test.** Each container shall be tested, with seams under water or covered with soapsuds or heavy oil, by interior air pressure of at least *7 pounds per square inch* for containers over 12 gallons capacity and *at least 5 pounds* for others. Equally efficient means of testing are authorized upon demonstration and proof of satisfactory tests to representatives of the Bureau of Explosives. Leakers shall be rejected or repaired and retested.

Port of New York Authority—"Supplement No. 1 to Information Regarding Traffic Rules, Regulations and Toll Rates." (Effective June 1, 1947.)

Pp. 1-2

3. No vehicle loaded with any Dangerous Article shall enter any tunnel unless the driver shall first, on demand made by a Port Authority police officer, exhibit a bill of lading or other shipping paper describing such article by the specific name therefor used the "List of Explosives and Other Dangerous Articles" contained in section 4 of the I.C.C. regulations; nor shall any vehicle loaded with any Combustible Liquid enter any tunnel unless the driver shall first, on demand made by a Port Authority police officer, exhibit a bill of lading or other shipping paper describing such liquid by name and stating the temperature or temperature range at or within which such liquid gives off an inflammable vapor as determined by flash-point as aforesaid.

4. Wherever reference is made herein to "I.C.C. regulations" it shall mean the regulations of the Interstate Commerce Commission in effect on the effective date hereof issued under the authority contained in sections 232-236, inclusive of the Criminal Code of the United States (as last amended by Public Act No. 809, 76th Congress), and included in Parts 71 to 85, inclusive of Title 49 of the Code of Federal Regulations dealing with the transportation of explosives and other dangerous articles by motor carriers by highway.

5. The following terms shall have the meanings given in the definitions of said terms in the I.C.C. regulations, and the commodities and articles defined and classified in said regulations under said terms shall be so defined and classified herein:

"Inflammable Liquid," "Inflammable Solid," "Oxydizing Material," "Corrosive Liquid," "Compressed Gas," "Noninflammable Compressed Gas," "Inflammable Compressed Gas," "Poisonous Article," "Poisonous Gas or Liquid, Class A," "Tear Gas or Irritating Substance, Class C," "Explosive," "Class A Explosive," "Class B Explosive," and "Class C Explosive."

"Combustible Liquid" shall mean any liquid which gives off an inflammable vapor at a temperature above eighty degrees (80°) and at or below one hundred fifty degrees (150°) Fahrenheit as determined by flash-point with the Tagliabue Open Cup Tester as used for test of burning oils.

"Dangerous Article" shall mean any Inflammable Liquid, Combustible Liquid, Inflammable Solid, Oxydizing Material, Corrosive Liquid, Compressed Gas, Poisonous Article or Explosive and any empty container formerly containing an Inflammable Liquid, or Inflammable Compressed Gas, or any Poisonous Article described in rule and regulation "17" hereof.

8. The presence in a tunnel of a vehicle loaded with any Dangerous Article, or of a tank truck formerly loaded with an Inflammable Liquid, is likely to endanger persons or property in the tunnel and render the use of the tunnel unsafe, and no such vehicle or tank truck shall be allowed in any tunnel unless it shall conform to these rules and regulations in addition to all other rules and regulations for the use of the tunnels.

9. No vehicle loaded with any Dangerous Article and no tank truck formerly loaded with an Inflammable Liquid shall enter any tunnel unless such vehicle, its load and the transportation of such load in such vehicle, shall in every respect comply with the I.C.C. regulations, including, without limiting the generality of the foregoing, regulations regarding forbidden articles, proper condition for transportation, containers, packing, marking, labeling, description, certification, quantity limitations and loading.

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11. INFLAMMABLE LIQUIDS. No vehicle shall enter any tunnel if its load shall include any Inflammable Liquid; unless

(a) such liquids shall be in glass or earthenware containers of one (1) gallon capacity or less or in metal drums or containers of five (5) gallons or less; and

(b) the load shall include no inside container with more than four (4) fluid ounces of Acrolein; and

(c) except as provided in sub-division (d) hereof, such Inflammable Liquid shall be so packed that it shall be exempt under the I.C.C. regulations from specification packing, marking and labeling requirements; and

(d) the quantity of any Inflammable Liquid in said load included in the following list, or having similar qualities, and not packed as provided in sub-division (c) hereof shall not exceed the quantities shown:

	Maximum Quantity per Vehicle	
	Contents (Gallons)	*Gross Wt. (Pounds)*
Carbon bisulfide (disulfide)	**100**	**1000**

Fire Fighting Procedures

Dry chemical powder extinguishers, carbon dioxide, and other inert gases may be used as an extinguishing agent for fires in carbon disulfide. Sand may be used on fires involving small quantities of the flammable liquid.

Water applied as a spray or fog may be utilized to cool and blanket carbon disulfide, which is heavier than water, particularly where it is confined to tanks or other containers.

Foam is not effective on carbon disulfide. Carbon tetrachloride should not be used.

Use of suitable gas masks or self-contained breathing equipment is recommended.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The primary purpose of this report is to record the sequence of events leading up to and during the fire, and to make suggestions to prevent a recurrence. It is expected that this fire will be the subject of study by all authorities with a viewpoint of promoting safety in tunnel operation.

It is obvious that regulations for the shipment of hazardous chemicals by motor carrier are difficult to enforce under present conditions. Despite the best efforts of the authorities, enforcement would be incomplete without cooperation of the shippers and motor carriers. Moral as well as legal responsibility is involved when commercial groups introduce large quantities of dangerous chemicals into public thoroughfares. Although the Holland Tunnel fire was merely an expensive and inconvenient occurrence, it should provide a grave warning against flagrant violations and lack of suitable provisions for enforcement of current regulations. It easily could have been a major disaster with the loss of many lives. Fire services and safety groups recognize the special hazards that are being presented by these veritable "warehouses on wheels." They are therefore fully justified in demanding more stringent checkups and sterner measures.

New legal safeguards to broaden the powers of the authorities are in the process of enactment at the time of this writing. All indications point to more severe regulations with greater penalties for violations. A positive safety program including a study of the various routes for the transportation of these dangerous materials is essential. Education of the shipper, trucker, and driver must be made the keynote to implement the full effect of this work. *It would be of little avail to inform the truckmen of what* **not** *to do without offering a safe alternative.* Particular emphasis must be placed on the protection of the public in tunnels, on bridges, in ferries, and on congested highways.

The Committee on Truck Transportation of the National Fire Protection Association has considered this problem in detail and has subdivided its recommendations under the following headings:

I. Design and Construction of Trucks, Bodies, Power Plants, and Electrical Equipment.

II. Shipping Containers.

III. Amount of Materials to Be Transported—Mixed Cargoes.

IV. Qualifications of Operators.

V. Operations of Trucks en Route—Parking.

VI. Extinguishing Equipment—Placards and Signs—Procedure in Case of Fire or Accident.

VII. Inspection and Maintenance of Trucks and Equipment.

VIII. Drivers Manual.

IX. Fire Reports.

The reports (Proceedings of Forty-fourth Annual Meeting of the National Fire Protection Association, Vol. 34, July, 1940, No. 1, pp. 224-250) which have emanated from this Committee to date, have been very complete and are entirely applicable to the problem. Certain supplementary suggestions specifically directed at the tunnel problem are being added to this available information.

Supplementary Recommendations

(1) A "safe routing" plan for the transportation of dangerous chemicals and explosives should be established for any area in which are included vehicular tunnels, bridges, and congested highways. Where required, warning notices of the following type should be conspicuously posted at the entrances to such vital facilities:

> TRANSPORTATION OF EXPLOSIVES AND CERTAIN QUANTITIES OF OTHER DANGEROUS ARTICLES THROUGH THIS TUNNEL IS PROHIBITED. INQUIRE OF PATROL OFFICER FOR SPECIAL ROUTE.

Consideration should be given to the use of special industrial ferries for heavy loads of hazardous cargoes not acceptable in tunnels and strategic bridges. Proper packaging, loading, and stowage should be considered essential to safe handling in transit.

(2) Pertinent information concerning the nature of dangerous chemicals and explosive cargo should be made available to the motor carrier by the shipper. Suitable labels and warning placards must be prominently displayed to be legible at reasonable distances and to facilitate inspection. The trucking and federal control groups should standardize on the size of such markings, the location, and the manner of affixing them to the trailers and trucks. The shipper should carry an ample supply of the required labels and placards at all times, and accept the responsibility of providing them to the trucker at the time of loading.

(3) The aforementioned data should be transferred to each driver who accepts subsequent responsibility for the cargo. These should be accompanied by instructions for taking any special routes and also include necessary precautions to be taken in the event of an emergency.

(4) Every emergency brings to attention certain worthwhile safeguarding suggestions. The critical role of the ventilation system in tunnels suggests that the exhaust fans be protected against fire damage by water sprays or other suitable means. Location of motors and drive mechanisms in areas separated from the exhaust chambers would greatly reduce the possibility of ventilation failure in serious fires. Other items worthy of consideration include the use of specially designed, combustion-suppressing drainage gutters and curb sumps, and, wherever necessary, the use of motors and electrical equipment approved for hazardous locations to guard against explosions in accidental spillage of gasoline and other flammable liquids. All critical load-bearing structural members of the ventilation ducts should be protected from fire damage and danger of collapse.

(5) Legislation governing the transportation of dangerous chemicals and explosives should be reviewed for the purpose of standardizing procedures and making the penalties for violation more severe when necessary. The permissible quantities of broken lots or mixed hazardous cargoes which are carried without warning signs on the outside of the vehicle should be reconsidered for the purpose of maintaining a more suitable factor of safety.

(6) To cope with fires at their incipiency, adequate first aid fire fighting appliances should be provided within tunnels. Because of various kinds of fires that may be encountered with different cargoes and conditions brought about through collision or upset, and the fact that no one type of extinguisher is best suited for the control of all fires, portable devices suitable for Class A and Class B fires should be located at frequent intervals to be close at hand when needed and should be placed to be conspicuously visible and brought into prominence with sharply contrasted painted areas. Extinguishers suitable for Class C fires should be placed near transformer vaults and similar electrical installations. Sand for diking of the roadway will be found effective in damming spilled flammable liquids and prevent their spread and flow into drains. Foam powder has been used for such purposes. Where the length of tunnel is such that long hose lines would be required to reach from the outside to a possible fire within, a standpipe system should be available for fire fighting.

(7) In view of the quantity of combustible material which may be carried in a single truck and the possibility of rapid spread of fire both by radiant heat and by direct contact, under congested and relatively confined conditions, the use of automatic sprinklers or other fixed water spray equipment to promptly control fires within tunnels is worthy of serious study.

(8) A cooperative educational program should be undertaken by the Interstate Commerce Commission, the American Trucking Association, Inc., and all state traffic and fire authorities to supplement the legislation and enforcement plans.