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16. Abstract

About 0924 e.s.t., on February 24, 1977, a Commonwealth of Pennsylvania, Department of Transportation, Piper PA-31T Cheyenne (N631PT) crashed shortly after takeoff from runway 8 at the Capital City Airport, New Cumberland, Pennsylvania. The aircraft crashed in a populated area in the town of Bressler, a suburb of Harrisburg, Pennsylvania. All occupants of the aircraft, six passengers and two pilots, were killed. A woman was also killed when the house in which she lived was destroyed during the crash. Several private and commercial properties were damaged severely. The aircraft was destroyed.

The National Transportation Safety Board determines that the probable cause of the accident was the flightcrew's failure to insure that the aircraft was loaded properly and that its center of gravity was within certificated limits. As a result, the aircraft's control characteristics were degraded significantly by a center of gravity position well aft of the certificated limits. This imbalance led to the pilot's inability to control a longitudinally unstable aircraft during a climbing turn in instrument meteorological conditions.

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

Adopted: January 5, 1978

COMMONWEALTH OF PENNSYLVANIA
PIPER PA-31T, N631PT
BRESSLER, PENNSYLVANIA
FEBRUARY 24, 1977

SYNOPSIS

About 0924 e.s.t., on February 24, 1977, a Commonwealth of Pennsylvania, Department of Transportation, Piper PA-31T Cheyenne (N631PT) crashed shortly after takeoff from runway 8 at the Capital City Airport, New Cumberland, Pennsylvania'. The aircraft crashed in a populated area in the town of Bressler, a suburb of Harrisburg, Pennsylvania. All occupants of the aircraft, six passengers and two pilots, were killed. A woman was also killed when the house in which she lived was destroyed during the crash. Several private and commercial properties were damaged severely. The aircraft was destroyed.

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1. FACTUAL INFORMATION

1.1 History of the Flight

On February 24, 1977, a Commonwealth of Pennsylvania, Department of Transportation (PennDOT), Piper PA-31T Cheyenne (N631PT) was being used to transport five PennDOT employees and a State official on a one-day trip which started from, and was to terminate at, Capital City Airport, New Cumberland, Pennsylvania. Intermediate stops were to have included St. Mary's and University Park in Pennsylvania.

About 0729, 1/ the pilots of N631PT were briefed by telephone on the en route weather by the Harrisburg Flight Service Station (FSS), located at Capital City Airport. About 0855, the copilot called Harrisburg FSS again to inquire about the height of the tops of the clouds.

About 0900, the six passengers, some of whom were seen carrying cameras and light briefcases, boarded the aircraft. At 0905, the crew of N631PT was cleared to taxi to runway 8. At 0907, N631PT received and acknowledged the following clearance from Capital City Airport Tower: "Cleared as filed, maintain 6,000, expect further clearance to 8,000 10 min after departure. Departing runway 08, maintain runway heading, vectors on course. Departure control frequency 124.1, squawk 0300." The tower delayed the aircraft's takeoff because of traffic.

At 0921, N631PT was cleared for takeoff. About 1 min later, the tower øcontroller instructed the flightcrew to switch their radio to the departure control frequency. About 30 sec later, the departure controller advised N631PT that radar contact had been established and instructed the pilot to turn his aircraft left to 360". The flightcrew of N631PT acknowledged: "Left, 360, roger." This was the last radio communication from N631PT.

According to witnesses who watched the takeoff, the aircraft made a "flat" liftoff from the runway. They saw the landing gear retract and the aircraft continue a shallow climb on what appeared to be the runway heading until it disappeared in the haze that covered the airport area.

Testimony of witnesses north and east of the departure end of runway 8 established a flight profile which included the left turn after takeoff, followed by a turn of about 270' to the right, then a turn of about 180" to the left. These witnesses also described a series of shallow climbs and descents during the turns. The last witness to see the aircraft before it crashed stated that the aircraft appeared 'to come

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1/ All times herein are eastern standard, based on the 24-hour clock.

out of the overcast in a steep descent which continued into the ground. He stated that, just before the impact, the aircraft disappeared from his sight behind a house. Then he saw the smoke and fire which followed the crash.

The crash site was in a residential area 1.55 statute miles from the departure end of runway 8. Weather in the area was characterized by low ceilings and visibilities.

The accident occurred during daylight hours, about 0934, at latitude 40° 13' 56" N and longitude 76° 49' 03" W. The elevation of the initial impact point was 509 feet m.s.l.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	2	6	1
Serious	0	0	0
Minor/None	0	0	0

1.3 Damage to Aircraft

The aircraft was destroyed.

1.4 Other Damage

A house, an outdoor cooking pit, and a utility shed were destroyed; three automobiles, a pickup truck, and a house trailer were heavily damaged. A garage and two houses were damaged by fire and flying debris. Trees, shrubs, lawns, and power lines in the ground path of the aircraft were also damaged.

1.5 Personnel Information

The two crewmembers were properly certificated for the flight. (See Appendix B.)

Both pilots had received PA-31T weight and balance training a month before the accident as a part of the ground school at the Piper Training Center at Lock Haven, Pennsylvania. This training was required in order for the two pilots to become familiar with the particular c.g. requirements of the PA-31T.

The pilot who occupied the right seat and was the pilot-in-command of the flight had also attended flight checkout training at Lock Haven. He had accumulated 32 flight-hours in the PA-31T. The pilot who occupied the left seat during this flight was scheduled to attend flight checkout training the week following the accident. He had accumulated 1.7 flight-hours in the PA-31T. Both pilots were well qualified in the PA-31--an earlier model of the 31-series Piper aircraft. No determination could be made as to which pilot was flying the aircraft at the time of the accident.

1.6 Aircraft Information

The aircraft was certificated, equipped, and maintained in accordance with applicable regulations.

The aircraft was equipped with a flight director system, consisting of a horizontal situation indicator and a director horizon, on the pilot's instrument panel. The copilot's side was equipped with an artificial horizon indicator and a directional gyro.

N631PT was leased by PennDOT from the Piper Aircraft Company. The term of the lease was 1 year beginning on February **1, 1977.** PennDOT was to provide all maintenance support and insurance coverage. Manufacturer's warranty was to be provided either by a local Piper distributor or by Piper Aircraft Company at Lock Haven, Pennsylvania.

At takeoff, about 2,160 lbs of jet-A fuel were on board. (See Appendix C.)

According to PennDOT personnel who observed the flightcrew of N631PT on the morning of the accident, a Model PA-31T Weight and Balance Visual Plotter was used to determine weight and balance information for the flight. The plotter, which is supplied with the aircraft, is an accepted means to determine this information and consists of an imprinted transparent face behind which is a movable slide. By matching information **on** the face of the plotter with information on the slide, weight and balance information can be obtained for specific aircraft loading situations. (This computation can also be made by the "long form" method which requires the use of charts from the aircraft's operating manual and a form to record each change and compute the final c.g. position. However, no weight and balance documentation could be found either at the PennDOT departure hanger office at Capital City Airport or in the wreckage.)

Instructions for its use as well as loading recommendations are **on** the back of the visual plotter. Step No. 3 of the instructions contains a caution that the proper portion of the plotter must be used for either aft or forward facing third and fourth passenger seats. N631PT had aft facing third and fourth seats. When other PennDOT pilots were asked to solve a weight and balance problem using the plotter, they invariably made computation errors involving these seat positions. Loading recommendation No. 5 states, "When carrying 8 occupants, front baggage compartment must be loaded to bring c.g. within 138.00 in. 2/ rearward limit. Fuel must be reduced to keep total weight within 9,000 lb limit. Locate heaviest occupants forward." According to witnesses who watched the aircraft being loaded, no baggage was loaded in the front compartment. Evidence at the accident site did not indicate that any baggage had been located in that compartment.

The seating location of only one passenger was known. The above weight and c.g. calculations are based upon a conservative loading schedule of seating the heaviest passengers forward in accordance with instructions in the Piper Pilot's Operating Handbook for loading eight occupants. These calculations do not include items carried aboard since their exact weight and cube are not known. Assuming that 50 lbs of such baggage had been stowed in the rear baggage compartment, takeoff c.g. could have been at 140.70 ins.

Using actual weights of crew and passengers taken from recent documents, the weight and balance was calculated following the accident, based on positioning the heaviest passengers forward. The maximum allowable takeoff weight was 9,000 lbs. The visual plotter was used to compute the following:

	LBS	ARM	MOMENT
Basic weight	5,389	130.1	701,108.9
Pilot and copilot	315	119.0	37,485.0
Seats 3 and 4 (aft)	410	159.0	65,190.0
Seats 5 and 6 (forward)	380	198.0	75,240.0
Seat 7 (forward)	180	229.0	41,220.0
Seat 8 (forward)	170	242.0	41,140.0
Fuel (320 @ 6.75)	2,160	138.9	300,024.0
	9,004		1,261,407.9

$$\frac{1,261,407.9}{9,004} = 140.09 \text{ ins. c.g.}$$

Investigators discovered that some of the passengers on board N631PT usually preferred to sit in certain seats. Their preferences, however, did not place the heaviest passengers forward in the cabin, but rather, placed the heaviest loads toward the back. Weight and balance, therefore, was also calculated for this seating arrangement. These calculations resulted in a c.g. of 140.60 ins. An additional 50 pounds of baggage in the rear baggage compartment would have resulted in a farther aft c.g. of 141.20 ins.

2/ All center of gravity figures are in ins. aft of the datum point--a point along the longitudinal axis of an aircraft used in connection with the aircraft's weight and balance computations.

Thus, the takeoff c.g. of N631PT could have been between 140.09 ins. and 141.20 ins., or from 2.09 ins. to 3.20 ins. aft of the approved maximum aft limit of 138.00 ins.

1.7 Meteorological Information

Surface weather observations at the Capital City Airport were made by FAA Flight Service Station personnel who were certificated by the National Weather Service (NWS). Surface observations taken at the airport before and after the accident were as follows:

0845 - Ceiling--indefinite, 500 ft obscuration; visibility--314 mi, fog, haze; sea level pressure--1,013.9 millibars; temperature--35°F; dewpoint--33°F; wind--110° at 10 kn.; altimeter setting--29.93 inHg.; runway 8 runway visibility--314 mile.

0930 - Local - ceiling--indefinite, 500 ft obscuration; visibility--314 mi, fog, haze; temperature--36°F; dewpoint--34°F; wind--120° at 10 kn; altimeter setting--29.90 inHg.; runway 8 runway visibility--1 mi.

There were no pilot's weather reports available via teletypewriter pertinent to the time and the place of the accident; however, about 0855, an earlier local pilot report was given by telephone to one of the flightcrew from N631PT. This report was as follows:

Three mi north of Lancaster (Pennsylvania) at 0736, flight altitude--4,000 ft, Convair 580, temperature--10°C; first layer tops--1,700 ft, second layer--5,700 ft, cirrus above.

No low-level turbulence was reported by aircraft arriving at Capital City Airport or at Harrisburg International Airport.

1.8 Aids to Navigation

Not applicable.

1.9 Communications

No air-to-ground communication difficulties were reported.

1.10 Aerodrome Information

Runway 8 at Capital City Airport, an asphalt-surfaced runway, is 4,970 ft long and 150 ft wide. It is equipped with high-intensity runway lights which were illuminated at the time of takeoff. The field elevation is 347 ft m.s.l.

1.11 Flight Recorders

No flight data recorder or cockpit voice recorder was installed in N631PT, nor was either required.

1.12 Wreckage and Impact Information

The first signs of contact were found 15 ft above the ground on a 23-ft tree. About 20 ft beyond the tree, the aircraft struck the macadam surface of a street. The marks in the street were made by the aircraft's fuselage and engine nacelles. Propeller slash marks were evident in the impact mark made by the left engine nacelle. The aircraft continued to slide on a magnetic heading of 075°. It struck and continued through a house which erupted in flames. The aircraft then struck and displaced an automobile in the driveway and a pickup truck parked in front of the house. The aircraft wreckage continued across another street and came to rest in a driveway against a telephone pole. The total wreckage area was about 755 ft long and about 210 ft wide. (See Appendix D.)

The aircraft broke up extensively. All but a few small aircraft parts evidenced some degree of ground fire damage. The nose and main landing gear and all flight control surfaces were found. There was no evidence on any structure examined to indicate in-flight fire, explosion, lightning strike, or bird strike. All structural fractures were typical of those caused by overload. The flaps were up and the three landing gear were retracted.

The pilot's and copilot's instrument panels were damaged extensively by impact and fire. No valid flight or engine instrument readings could be obtained. The flight attitude indicators were damaged extensively.

The stall sensor vane for the stability augmentation system was separated from the aircraft and was located along the wreckage path. The carbon dioxide (CO_2) bottle for the system was located within the burned cockpit section. This bottle sustained fire damage and was discharged. The stability augmentation emergency actuator was found intact and attached to the fuselage structure at fuselage station (FS) 274. The actuator piston rod was in the fully extended position with its lock tab in place. The hydraulic line to the actuator was separated at the actuator attaching fitting. The actuator was removed and found to contain hydraulic fluid. The servo actuator arm was found attached within FS 274. The servo arm was in the full down position and all attaching cables were connected.

The elevator down spring was separated from the aircraft and was stretched beyond its limits; one end loop was straightened out but was not broken. The hydraulic reservoir for the stability augmentation system was attached to the aft fuselage. The reservoir contained about 1/4 in. of fluid which corresponded to the normal operating level indicated on the side of the reservoir.

Both engines were examined. There were **no** indications of engine failure or malfunction before the crash.

The cabin air recirculating fan was separated from the aircraft. The fan blades were twisted around the fan drive shaft. The unit did not show evidence of fire damage or sooting.

1.13 Medical and Pathological Information

The eight occupants of the aircraft died of impact trauma. The occupant of the destroyed house died of a combination of impact trauma and burns.

A review of the flightcrew's autopsies and toxicological examinations disclosed no evidence of pre-existing physical or physiological problems which could have affected their judgment or performance.

1.14 Fire

The aircraft erupted in flames upon impact with the street. Aircraft fuel from the ruptured fuel cells fed the fire. The 50-ft-wide burned area continued from the initial impact point for about 200 ft along the wreckage path. Fire erupted again when the aircraft wreckage struck and continued through a house. This fire was restricted to the house and immediate area around the house; it did not continue along the wreckage path. There was also fire in the area in which the wreckage came to rest.

The Bressler Volunteer Fire Company, located about five blocks from the accident site, responded to the accident within minutes. The other six volunteer fire companies which comprise the Swatara Township Fire Department responded shortly thereafter. The fires were under control about 20 min after the crash; however, about an hour was required to put out the fire in the destroyed house.

1.15 Survival Aspects

The accident was not survivable.

1.16 Tests and Research

The stability and control characteristics of the PA-31T Cheyenne for a c.g. location between 140.10 ins. and 141.30 ins. were not known at the time of the accident since neither the manufacturer nor the FAA had conducted, nor were they required to conduct, flight tests at these aft c.g. values.

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Because of the potential significance of the aircraft's flight characteristics at these c.g. positions to the operational circumstances of this accident, the National Transportation Safety Board contracted the Calspan Corporation of Buffalo, New York, to conduct, under the direction of the Board, a stability evaluation of the Cheyenne for c.g. locations extending to 141.30 ins. With the cooperation of the Piper Aircraft Corporation, Calspan simulated the Cheyenne's flight characteristics in a variable stability B-26 airplane. 3/

The variable stability B-26 aircraft provides the capability of varying electronically the servo characteristics which govern aircraft's stability and pilot control forces in accordance with pre-programmed inputs. The system was programed to simulate the Cheyenne aircraft in the 140 KIAS climb power condition. Any c.g. location between 131.90 ins. and 141.30 ins. could be selected for evaluation. During the in-flight simulation, the evaluation pilot flew the B-26 aircraft through the special variable stability system which produced pitch responses and elevator control forces (stick forces) and positions which were representative of the Cheyenne aircraft.

The primary objective of the simulation program was to evaluate the longitudinal flying qualities of the Cheyenne aircraft at various c.g. locations. Accordingly, the evaluations involved three c.g. locations: 134.00 ins., representative forward c.g. and a benchmark for comparison with Cheyenne aircraft; 138.00 ins., the certified aft c.g. limit; 141.30 ins., an approximate aft c.g. simulation limit.

Three evaluation pilots were used in the program; none of the pilots had significant experience in the Cheyenne aircraft. In addition, the simulation was sampled by a qualified Cheyenne pilot from Piper Aircraft Corporation and Calspan engineering pilots.

For each evaluation, the pilot was asked to attempt to fly successfully a flight profile similar to that of the accident aircraft. Briefly, the pilot was given control of the simulator aircraft in-flight at 125 KIAS and 400 ft above the runway; he applied climb power, accelerated to 140 KIAS and began a visual climbing turn. At 900 ft above ground he began flying the aircraft by reference to instruments and followed a prescribed instrument departure. Realistic radio clearances and peripheral tasks were included in an attempt to simulate a realistic distraction level. Each pilot evaluated the c.g. locations in the order listed and commented on pilot performance, speed control, and attitude control. The pilots had no knowledge of the details of each configuration and typically flew two complete flight profiles at each c.g.

3/ "In-flight Simulation of a Piper PA-31T Cheyenne, Calspan Report No. AK-6139-F-1, 6 July 1977."

Pilot comments for each of the c.g. locations evaluated are summarized below:

At 134.00 ins.

Characteristics

- Forward c.g.
- Stable steady stick force and position gradients with speed changes from the trim (zero stick force) airspeed
- Stick force' per "g" = 19 lb/g
- Medium frequency, well damped short-period response
- Slightly unstable, long-term stick-free dynamic response.

All of the pilots agreed that the aircraft, at this c.g. location, was satisfactory for normal operation. However, two of the pilots commented on the high response to control inputs which is consistent with the relatively low value of longitudinal stick force per g for a wheel control transport aircraft. The pilots agreed that the simulated instrument flight profile, with its associated intentional distractions, was realistic.

At 138.00 ins.

Characteristics

- Aft certified c.g. limit
- Stable steady stick force gradient with speed changes from the trim airspeed
- Unstable steady stick position gradient with speed changes from the trim airspeed
- Stick force per "g" = **9** lb/g
- C.g. aft of stick-fixed neutral point: Statically unstable, 5 secs to double the amplitude of pitch divergence with stick fixed
- Stick-free long-term response dynamically unstable
- Short-period response, low frequency, well damped.

All the pilots commented adversely about the longitudinal flying qualities of the aircraft with this c.g. location. They complained of a tendency to overcontrol (related to very low stick force per g value) and a tendency of the aircraft to wander off in attitude and airspeed (related to the effects of the static instability when the pilot holds the stick) when the pilot was not paying close attention. The dynamically unstable stick-free airspeed response modulated the forces with speed changes and no doubt contributed to the tendency to overcontrol. Workload was high; much attention was required. While the aircraft was not unsafe, its performance was considered undesirable 4/ because of the deficiencies. However, one pilot commented that an inexperienced pilot could get into problems in an actual instrument situation.

Pilot performance was degraded from the standard of the forward c.g.: Normal acceleration excursions were ± 1/2 g, or twice the forward c.g. excursions. Pilots commented that the aircraft had an uncomfortable feeling which was related to overcontrolling the pitch.

At ***141.30*** ins.

Characteristics

- C.g. aft of stick-fixed and stick-free neutral points: Position and force gradients with changes in speed from trim airspeed are unstable.
- Two secs to double the amplitude of each divergency with stick-fixed.
- C.g. at stick-free maneuver point: Stick force per "g" is zero.

All the pilots commented that the aircraft was unstable and oversensitive in pitch. The aircraft was difficult to trim, tended to wander off in pitch attitude and airspeed with any pilot inattention and corrections were difficult to make. This c.g. location was considered unsafe for normal operations by all the evaluation pilots. Performance was poor with large, uncomfortable excursions from the desired pitch attitude and speed. Excursions of ±3/4 g in normal acceleration and -20 kn to +40 kn airspeed deviations from trim airspeed were common.

At this c.g., the aircraft is essentially at the stick-free maneuver point of ***141.30*** ins. where the aircraft has neutral maneuvering stability. At trim speed, the stick force per g in accelerated flight

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4/ In context with pilot evaluations of aircraft handling qualities, undesirable essentially means that the pilot can do the task but there are deficiencies in the aircraft that he would like fixed.

is zero. Pilot control feel in maneuvers is typically poor and is reversed for maneuvers off the trim speed. One pilot commented that in IFR weather conditions he "could imagine losing control of the aircraft."

1.17 Additional Information

1.17.1 Stability Augmentation System

The stability augmentation system (SAS), in the Piper PA-31T aircraft is required in order to satisfy certification requirements regarding static longitudinal stability.

The SAS consists of an angle-of-attack sensing vane, a computer; a stall margin indicator, warning light, and warning horn; a SAS servo; a fault monitor system; and a test switch.

The SAS automatically improves the static longitudinal stability of the airplane by providing variable elevator force. This variable force stems from a servo actuated downspring which increases the stick forces at slow speeds (below about 120 kns calibrated airspeed (KCAS)). An angle-of-attack sensing vane on the right side of the fuselage nose section signals the SAS computer which powers the elevator downspring servo. The SAS computer also activates the stall-warning horn and provides the signal for the visual stall margin indicator on the upper left side of the instrument panel. Sensing vane heat is controlled by the left pitot heat switch.

The SAS test panel, located on the pilot's instrument panel, provides a test switch for preflight checking of the SAS and fault lights to indicate SAS malfunctions. Should the SAS malfunction, the lights will illuminate continuously until the malfunction is corrected. If the malfunction is caused by a power failure, the "power" warning light will illuminate; if the malfunction is caused by a computer, a sensing vane, or a servo failure, the "ram" warning light will illuminate.

The SAS is equipped with a stability augmentor override system. Should the SAS fail to function satisfactorily during flight, the pilot can override the system by removing the access cover on the right side of the pilot's control pedestal and pulling the lanyard actuator handle. The override is pneumatically operated. When the lanyard actuator handle is pulled, compressed gas is released from the CO_2 cartridge into a cylinder located in the aft section of the fuselage. Under normal operating conditions, the cylinder is filled with hydraulic fluid and the piston and rod assembly in the cylinder is in the down position, where it has no effect on the elevator downspring. When the lanyard actuator is pulled, the CO_2 is discharged through a line and into the cylinder, which drives the piston and rod assembly upward. The rod locks into place, keeping a constant tension of about 20 additional lbs on the elevator downspring; thus suitable handling characteristics for the flight are provided. At the same time, the hydraulic fluid is forced from the cylinder into the reservoir **on** top of the fuselage, where it is held until the override system is rearmed.

1.18 New Investigation Techniques

None

2. ANALYSIS

The flightcrew was properly certificated. There was **no** evidence of medical or physiological problems that might have affected their performance.

The aircraft was certificated, equipped, and maintained according to applicable regulations. Examination of the aircraft's airframe and powerplants revealed **no** evidence **of** malfunctions which would have been a factor in this accident.

The aircraft's systems were examined to determine the reason for the **loss of** aircraft control. All systems were damaged extensively by impact and fire; however, some definitive information was available. The electrical system was operational because radio transmissions were made from the aircraft just after takeoff and the fan blades of an electrically driven cabin air recirculating fan found in the wreckage showed high rotational forces at the time of impact.

No definitive information was available from either the pilot's or copilot's flight attitude instruments. However, since no failure could be found in the aircraft's electrical or pneumatic systems and since there were **no** previous problems with either instrument, the Safety Board does not believe that the two instruments failed simultaneously nor that there was, in fact, a failure in either instrument.

No evidence was found of problems related to the aircraft's pitot static system; the flightcrew reported no such problems during takeoff or during acknowledgment of the heading change request after takeoff. There were no indications that pitot heat was on; however, even had it been off, the aircraft would not have encountered freezing conditions until about **1,000** ft above ground level, and it is doubtful that N631PT attained that altitude for more than a few seconds during its short flight. Therefore, the Safety Board concludes that there was **no** icing or other malfunction of the pitot static system.

All flight control system components were found in the aircraft wreckage. None of these components, including the flight control cables, exhibited fractures or failures other than those caused by impact and fire.

All SAS components were found in the aircraft wreckage. Even though the CO_2 bottle for the manual activation. of the system had been discharged, evidence indicates that it discharged during aircraft breakup. The remainder of the system's components were found in their normal flight configurations. The normal operation of the SAS affects flight control characteristics only at speeds of about 120 KCAS or less and requires about 17 sec at this reduced airspeed to become fully effective. Any longitudinal divergence initiated by the flightcrew at a speed of 120 KCAS would get little or no reaction from the SAS. The PA-31T's norma? climb speed is about 139 KIAS (about 135 KCAS). During the investigation, other PennDOT personnel indicated that in the PA-31T their practice was to climb at an airspeed slightly higher then the recommended 139 KIAS. Therefore, it is not likely that the SAS was operating or-affecting N631PT's flight for the period of time the aircraft was airborne because of the probability of the higher airspeed.

Witnesses' observations and testimony from PennDOT personnel who watched the flightcrew and passengers board and load N631PT on the morning of the accident indicate that the aircraft was loaded in a manner which placed the aircraft's c.g. well beyond the approved aft c.g. limit of 138.00 ins. From information received from witnesses, the exact c.g. at takeoff could not be determined; however, using known weights for the flightcrew and passengers and estimated weights for briefcases and equipment placed on board the aircraft, a fairly accurate computation of the aircraft's actual c.g. at takeoff was made.

Using the most favorable loading of the passengers and baggage, 140.09 ins.--2.09 ins. aft of the approved rear limit--is the most forward c.g. which could be calculated. The worst c.g. situation--placing the heaviest passengers in the rear seats--was also calculated. A c.g. of 141.20 ins.--3.2 ins. aft of the approved rear limit--would be probable under these conditions. Therefore, at takeoff, the c.g. of N631PT was between 140.09 ins. and 141.20 ins--2.09 ins. to 3.2 ins. aft of the approved rear limit of 138.00 ins. The Safety Board concludes that, based on information relative to the passengers' seating preferences when flying, the actual c.g. of the aircraft at takeoff would have been closer to 141.20 ins. than to 140.09 ins.

This c.g. position of 141.20 ins. resulted in flight characteristics which were both statically and dynamically unstable. The stick forces which the pilot would have experienced in his attempt to control the aircraft would have differed from the normal in such a manner that his ability to control the aircraft would have been impaired. While pilot inputs to initiate a maneuver or to change airspeed would have been normal, stick force-airspeed gradients would have been reversed, that is, to stabilize the aircraft at a reduced airspeed would probably have required a push force instead of the normal pull force, and to stabilize it at 'an increased airspeed would have probably required a pull force instead of the normal push force. Moreover, the maneuvering stick force-load factor gradient would have been essentially zero, which would have resulted in poor aircraft control "feel" and a similar reversal in stick force requirements for maneuvers off the trim speed.

A stable aircraft, when disturbed from its trimmed flight attitude, will tend to return to the initial attitude without pilot input. However, the unstable aircraft, with an extreme aft c.g., will continue to diverge in the direction of the initial disturbance until the pilot reacts with an opposite from normal control input. The control forces required to stabilize the accident aircraft would have been quite low. As a result, the pilot's normal reaction to the situation would be to exert more force than necessary to stop the divergence. Therefore, a divergence in the opposite direction becomes probable. The resulting pilot-induced oscillation could eventually cause complete loss of control.

Although the pilot could, under relatively favorable conditions, modulate his control inputs to maintain a steady flightpath, the attention and workload required to do so might be compromised by the performance of other necessary flight duties in an IFR environment. Any slight inattention to aircraft control would quickly precipitate aircraft divergence, which would increase at a rapid rate as airspeed reduced. For a c.g. position of 141.20 ins., the time to double the pitch divergence amplitude according to Calspan Corporation flight tests, is about 2 secs.

In this accident since the maneuvering stick force gradient was zero, overcontrol of the aircraft or a pilot induced oscillation would have resulted following a divergence since the pilot would have found it difficult to avoid unwanted inputs. Consequently, the probability of recovery after the divergence was recognized would have been problematical. The pilot probably was not able to trim the aircraft in the short time following takeoff. He may have merely modulated the divergence of the aircraft for a brief time before matters became uncontrollable by periodically pushing and pulling on the control wheel in an attempt to set pitch attitude.

On this takeoff, the flightcrew of N631PT probably ignored the misloading of their aircraft. Although they may have been aware that certain degraded flight characteristics should be expected from an extreme aft c.g., the sudden departure from normal aircraft performance would have, in this case, caught them unaware. The extra workload imposed by the instrument meteorological conditions with no visible horizon, both pilots' low experience level in this aircraft, and a turn shortly after takeoff would have added to the confusion caused by the aircraft's erratic deviations from expected standard climb characteristics. The Safety Board concludes that, because of the confusion brought about by these conditions, the pilots allowed the aircraft to diverge from the normal departure profile and then overcontrolled the aircraft into an unsafe condition during recovery attempts. This overcontrol then increased in amplitude until the aircraft crashed.

Since each pilot had over *4,000* flight-hours, held an Airline Transport Pilot Certificate, and was a qualified flight instructor, they should have **known** how to correctly compute the c.g. for any aircraft and should have been aware of the consequences of an incorrect computation. The Safety Board concludes that, because of their previous experience and their training at the Piper Aircraft Company, both pilots should have been qualified to use the PA-31T visual plotter. Therefore, they should have known that N631PT was out-of-balance and should have either cancelled the flight or redistributed the load to bring the aircraft within certificated c.g. limits.

3. CONCLUSIONS

3.1 Findings

1. The aircraft was certificated and maintained according to approved procedures.

2. The crewmembers were certificated and qualified for the flight.

3. The aircraft was near the maximum allowable takeoff weight limit; however, the aircraft's c.g. position at takeoff was about 3.2 **ins.** aft of the rear c.g. limit for flight.

4. The flightcrew did not follow recommended procedures for aircraft loading with eight passengers onboard.

5. The flightcrew did not compute correctly the aircraft's c.g. for takeoff.

6. The estimated accident c.g. position was definitely aft of the stick-free neutral point and probably at or close to the stick-free maneuver point.

7. Normal stick force-speed gradients would have been reversed, that is, a reduction in airspeed would have required a push force while an increased airspeed would have required a pull force.

8. Maneuvering stick force gradients would have been extremely low or essentially zero.

9. The aircraft would have exhibited a tendency toward dynamic divergence with a time to double the amplitude of pitch divergence (for a c.g. position of 141.20 ins.) of about 2 secs.

10. The experience of the accident crew in PA-31T aircraft was relatively low.

11. The adverse control characteristics of the aircraft were compounded by an IFR environment and by flightcrew workload.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the flightcrew's failure to insure that the aircraft was loaded properly and that its center of gravity was within certificated limits. As a result, the aircraft's control characteristics were degraded significantly by a center of gravity position well aft of the certificated limits. This imbalance led to the pilot's inability to control a longitudinally unstable aircraft during a climbing turn in instrument meteorological conditions.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Acting Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PHILIP A. HOGUE
Member

/s/ JAMES B. KING
Member

January 5, 1978

4. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Safety Board was notified of the accident about 1015 on February 24, 1977. The investigation team went immediately to the scene. Working groups were established for operations, witnesses and air traffic control, structures and systems, maintenance records, powerplants, weather, and aircraft performance.

Participants in the on-scene investigation included representatives of the Federal Aviation Administration, the Pennsylvania Department of Transportation, Piper Aircraft Corporation, the Pratt & Whitney Aircraft Division of United Technologies Corporation, and Hartzell Propeller, Inc.

2. Public Hearing

A 2-day public hearing at Harrisburg, Pennsylvania, began on April 21, 1977. Parties represented at the hearing were the Federal Aviation Administration, the Commonwealth of Pennsylvania's Bureau of Aviation, and Piper Aircraft Corporation.

APPENDIX B

PERSONNEL INFORMATION

Mr. David M. Wolf

Mr. David M. Wolf, 35, was the pilot-in-command of the flight and occupied the right seat. He was employed by the PennDOT as Chief Pilot of the Executive Flight Department. He held Airline Transport Pilot Certificate No. 1642783 with commercial privileges, airplane single- and multiengine land, rotorcraft, helicopter, and instrument helicopter ratings. He also held a flight instructor instrument rating in airplane single- and multiengine. He had a first-class medical certificate dated February 2, 1977, with no limitations.

Mr. Wolf received a biennial flight check on July 26, 1976. He had completed PA-31T ground school and flight checkout training at the Piper Training Center at Lock Haven, Pennsylvania, in January 1977. He had accumulated 4,469 flight-hours, 32 of which were in PA-31T aircraft.

Mr. Edwin L. Soisson

Mr. Edwin L. Soisson, 36, occupied the left seat of N631PT on the day of the accident. He was employed as a staff pilot in the Executive Flight Department of PennDOT. Mr. Soisson held Airline Transport Pilot Certificate No. 1749850 with commercial privileges and airplane single- and multiengine land ratings. He also held a flight instructor/instrument rating in airplane single- and multiengine. He had a first-class medical Certificate dated February 2, 1977, with the limitation that he must wear glasses for distant vision while flying.

Mr. Soisson received a biennial flight check on July 12, 1976. He had completed PA-31T ground school at the Piper Training Center in Lock Haven, Pennsylvania, on February 7, 1977. He had accumulated 4,424 flight-hours, 1.7 of which were in the PA-31T aircraft.

APPENDIX C

AIRCRAFT INFORMATION

Piper Aircraft Corporation PA-31T, serial No. 31T-7720001, N631PT, was manufactured in September 1976 under FAA type certificate No. A-8EA. The aircraft was leased to PennDOT February 1, 1977. It was certificated and maintained according to procedures approved by the FAA. At the time of the accident the aircraft had accumulated 173.5 flight-hours.

Engines: Two Pratt & Whitney PT6A-28

Position	Serial No.	Total Time (hrs)
No. 1	PC-E 51174	173.5
No. 2	PC-E 51173	173.5

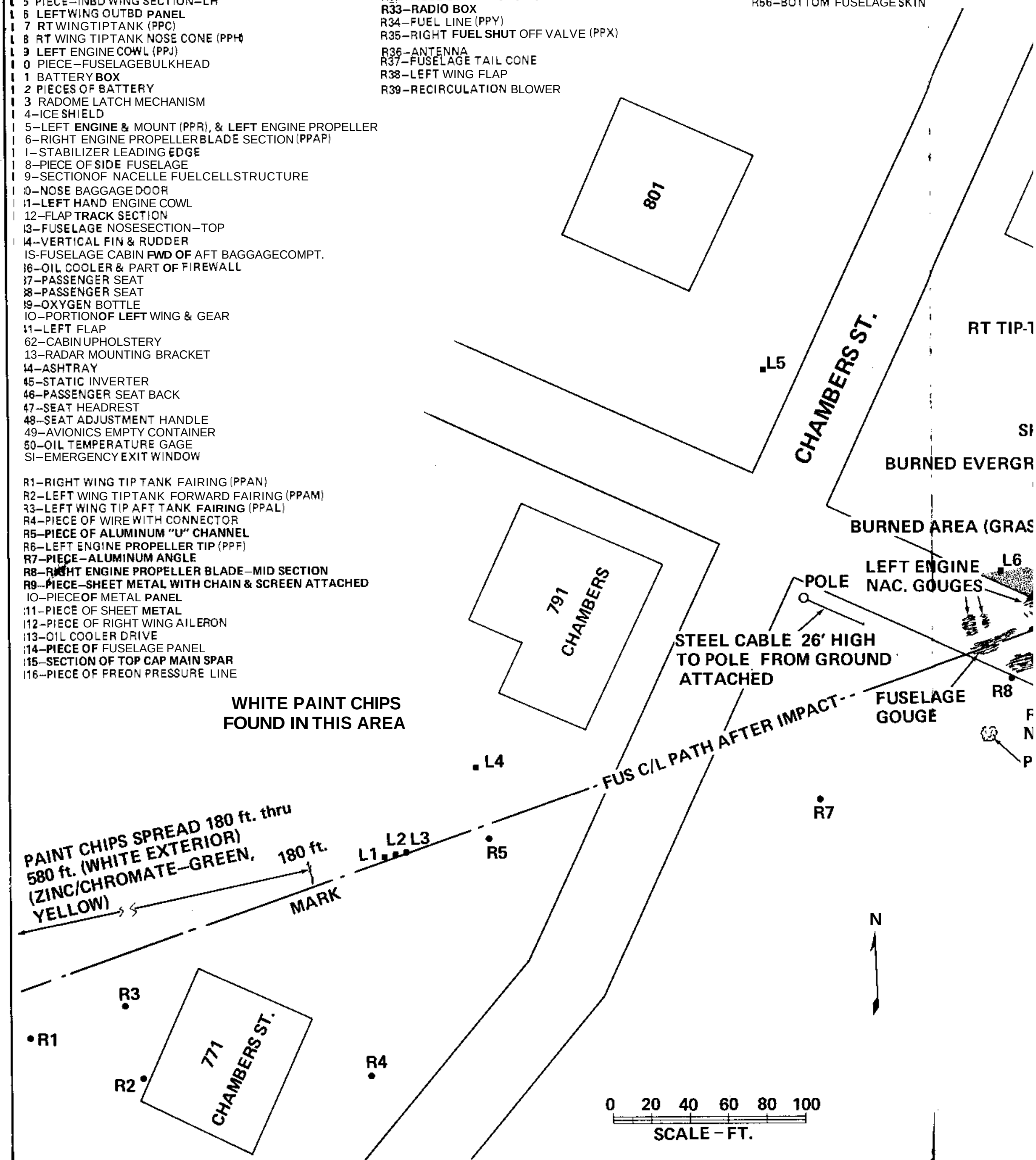
Propellers: Two Hartzell Model No. HC-B3TN-3B

Position	Hub Serial No.	Blade Serial No.	Total time (hrs)
No. 1	BU 6619	D 34434	173.5
		D 30836	
		D 35571	
No. 2	BU 6749	D 30766	173.5
		D 32514	
		D 30992	

EGEND:

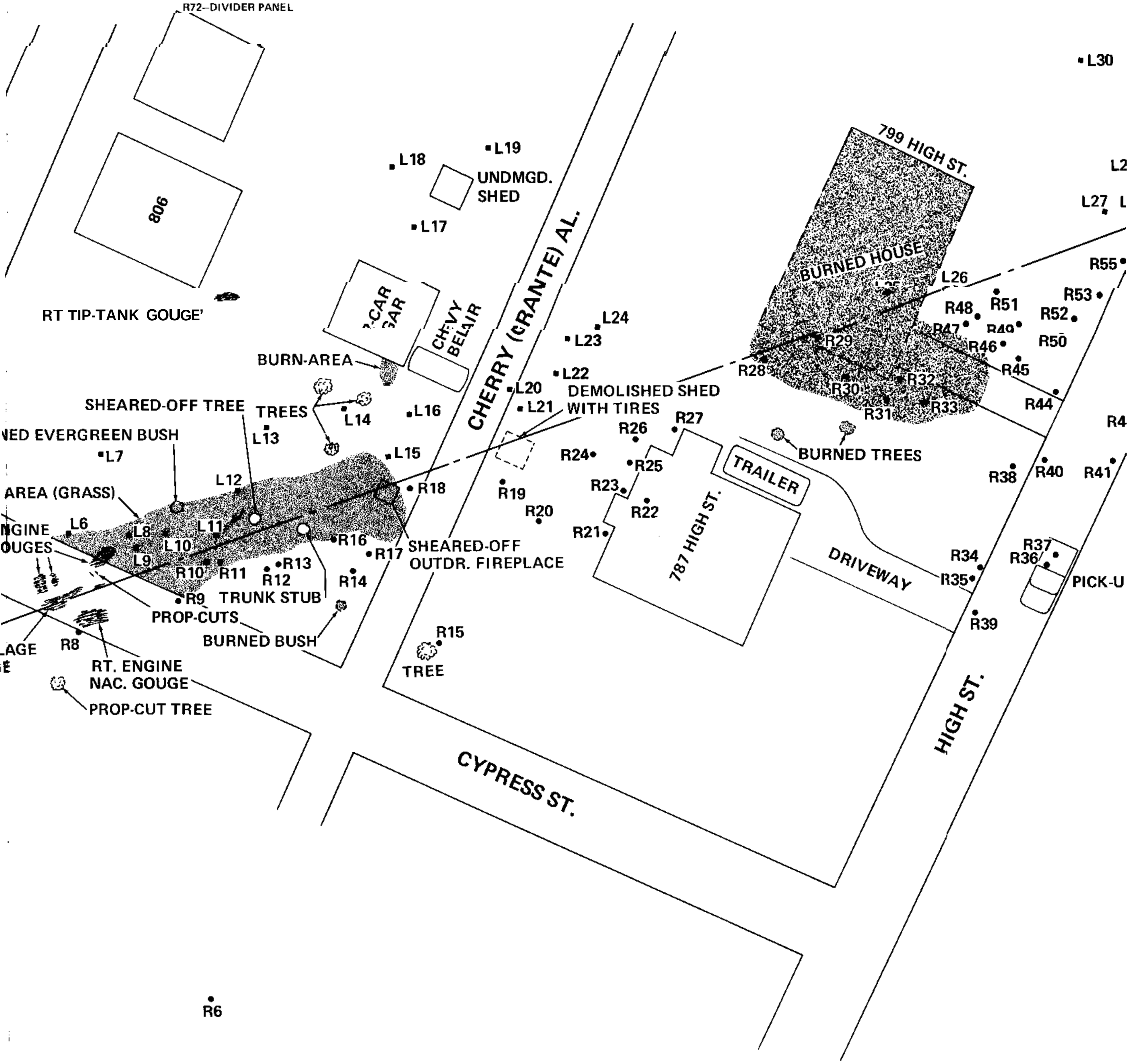
1 TIPTANK RUBBER BEADING
2 SMALL PIECE OF ALUMINUM
3 RT. TIPTANK AFT FAIRING
4 RT. PROPELLER TIP (PPAO)
5 RT. PROPELLER TIP (PPA)
6 WING BOTTOM SKIN
7 NOSE ACCESSPANEL
8 LEFT PROPELLER TIP (PPE)
9 COWL DOOR
10 WING BOTTOM SKIN
1 I OUTBD MAIN GEAR DOOR
1 2 INBD PANEL–WITH DRAIN–BOT FUSELAGE & NAC
1 3 LFT WING AILERON
1 1 WING VENT FUEL LINE
1 5 PIECE–INBD WING SECTION–LH
1 6 LEFT WING OUTBD PANEL
1 7 RT WING TIPTANK (PPC)
1 8 RT WING TIPTANK NOSE CONE (PPH)
1 9 LEFT ENGINE COWL (PPJ)
1 0 PIECE–FUSELAGE BULKHEAD
1 1 BATTERY BOX
1 2 PIECES OF BATTERY
1 3 RADOME LATCH MECHANISM
1 4–ICE SHIELD
1 5–LEFT ENGINE & MOUNT (PPR), & LEFT ENGINE PROPELLER
1 6–RIGHT ENGINE PROPELLER BLADE SECTION (PPAP)
1 I–STABILIZER LEADING EDGE
1 8–PIECE OF SIDE FUSELAGE
1 9–SECTION OF NACELLE FUEL CELL STRUCTURE
1 :0–NOSE BAGGAGE DOOR
1 :1–LEFT HAND ENGINE COWL
1 12–FLAP TRACK SECTION
l3–FUSELAGE NOSE SECTION–TOP
1 l4–VERTICAL FIN & RUDDER
IS-FUSELAGE CABIN FWD OF AFT BAGGAGE COMPT.
l6–OIL COOLER & PART OF FIREWALL
l7–PASSENGER SEAT
l8–PASSENGER SEAT
l9–OXYGEN BOTTLE
IO–PORTION OF LEFT WING & GEAR
l1–LEFT FLAP
62–CABIN UPHOLSTERY
13–RADAR MOUNTING BRACKET
l4–ASHTRAY
45–STATIC INVERTER
46–PASSENGER SEAT BACK
47–SEAT HEADREST
48–SEAT ADJUSTMENT HANDLE
49–AVIONICS EMPTY CONTAINER
50–OIL TEMPERATURE GAGE
SI–EMERGENCY EXIT WINDOW

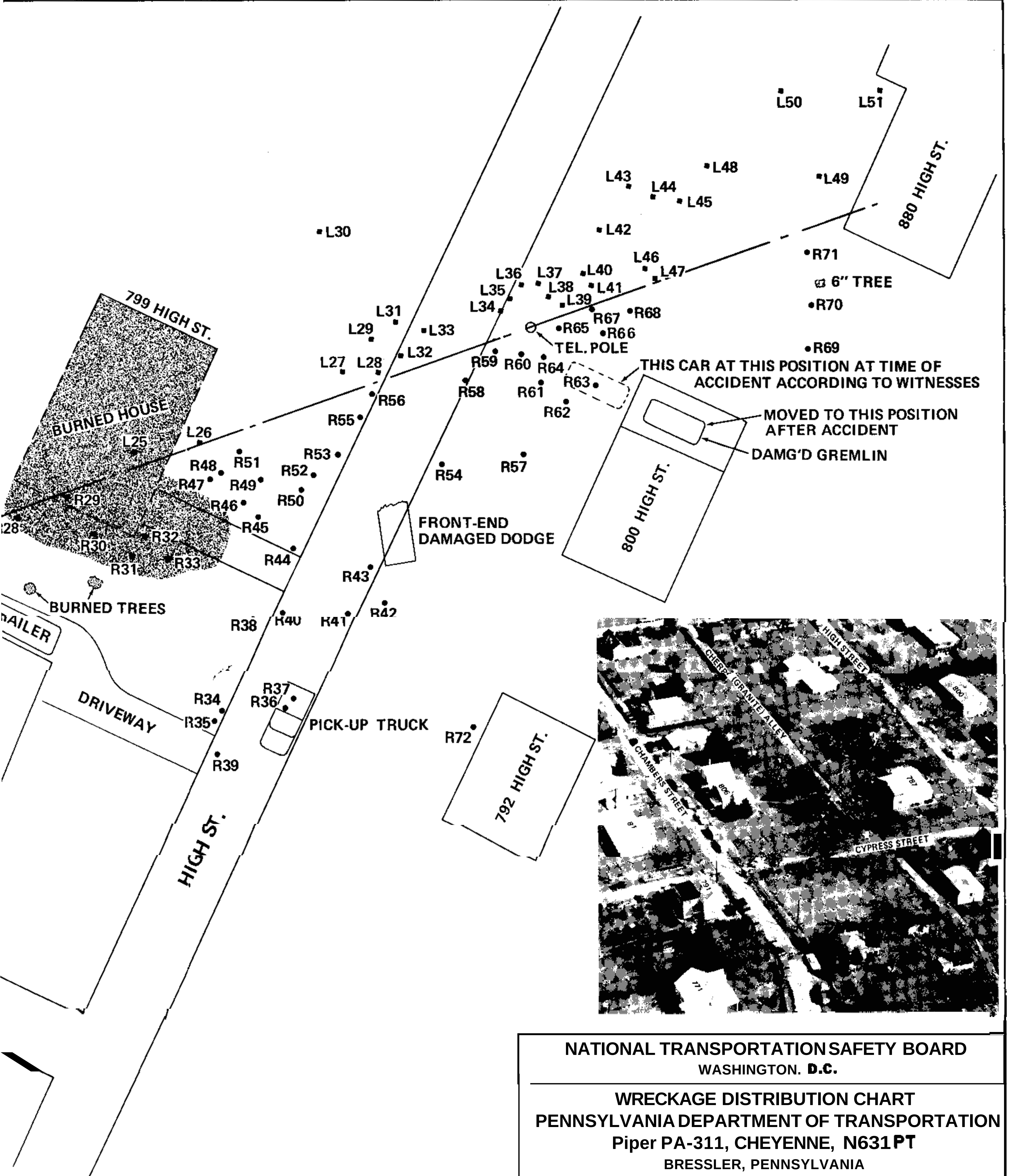
R1–RIGHT WING TIP TANK FAIRING (PPAN)
R2–LEFT WING TIPTANK FORWARD FAIRING (PPAM)
R3–LEFT WING TIP AFT TANK FAIRING (PPAL)
R4–PIECE OF WIRE WITH CONNECTOR
R5–PIECE OF ALUMINUM "U" CHANNEL
R6–LEFT ENGINE PROPELLER TIP (PPF)
R7–PIECE–ALUMINUM ANGLE
R8–RIGHT ENGINE PROPELLER BLADE–MID SECTION
R9–PIECE–SHEET METAL WITH CHAIN & SCREEN ATTACHED
IO–PIECE OF METAL PANEL
:11–PIECE OF SHEET METAL
!12–PIECE OF RIGHT WING AILERON
!13–OIL COOLER DRIVE
:14–PIECE OF FUSELAGE PANEL
!15–SECTION OF TOP CAP MAIN SPAR
!16–PIECE OF FREON PRESSURE LINE
R17–LEFT WING TIP TANK TAIL CONE
R18–ADF LOOP
R19–RIGHT WING FLAP ACTUATOR SCREW
R20–RIGHT FLAP
R21–31 INCH SECTION RIGHT ENGINE PROPELLER BLADE (PPC)
R22–PIECE RIGHT ENGINE REDUCTION GEAR (PPZ)
R23–RIGHT ENGINE PROPELLER BLADE CLAMP SECTION (PPK)
R24–RIGHT ENGINE PROPELLER BLADE CLAMP SECTION (PPL)
R25–SECTION OF RIGHT ENGINE REDUCTION GEAR BOX (PPT)
R26–PIECE OF RIGHT WING ROOTFAIRING
R27–RIGHT WING STROBE LIGHT POWER SUPPLY (PPW)
R28–PIECE OF PROPELLER
R29–LEFT WING TIP TANK
R30–PIECE OF SHEET METAL
R31–SECTION OF UPHOLSTERY PANEL–REAR CABIN
R32–PIECE OF FLAPSECTION
R33–RADIO BOX
R34–FUEL LINE (PPY)
R35–RIGHT FUEL SHUT OFF VALVE (PPX)
R36–ANTENNA
R37–FUSELAGE TAIL CONE
R38–LEFT WING FLAP
R39–RECIRCULATION BLOWER
R40–RIGHT ENGINE MISCELLANEOUS ACCESSORI
R41–FLOOR BOARD
R42–PANEL WITH PLACARD–"FULL OXYGEN"
R43–LANDING GEAR DOOR
R44–WINDSHIELD WIPER AND MOTOR
R45–AVIONICS BOX
R46–PIECE OF LEFT ENGINE COW
R47–PIECE OF WINGTIP FAIRING
R48–VERTICAL FIN TIP
R49–AIR BLOWER
R50–SECTION OF WING LEADING EDGE
R51–STROBE LIGHT AMPLIFIER
R52–MAIN ENTRVOOOR CYLINDER
R53–PIECE OF RADOME
R54–COWL FLAP ACTUATOR
R55–HORIZONTAL STABILIZER
R56–BOTTOM FUSELAGE SKIN



IEOUS ACCESSORIES (PPV)
ULL OXYGEN"
IOTOR
IWL
G
IG EDGE
IDER

R57–NACELLE ICE DEFLECTOR &DOOR MECHANISM ACTUATOR
R58–RIGHT ENGINE (PPS)
R59–HORIZONTAL STABILIZER FRONT SPAR
R60–RIGHT STABILIZER LDG EDGE
R61–RIGHT WING OUTBOARD PANEL
R62–MAIN ENTRY DOOR
R63–LEFT ENGINE BETA RING (PPU)
R64–RIGHT TANK TWIN BOOST PUMP (PPAD)
R65–NOSE GEAR STEERING MECHANISM
R66–FIRE EXTINGUISHER BOTTLE
R67–PROPELLER SPINNER
R68–MAIN WING CENTER SECTION SPLICE CAP
R69–FOLDING TABLE
R70–JANITROL HEATER
R71–PASSENGER SEAT
R72–DIVIDER PANEL





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