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TECHNICAL NOTE

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DAMAGE INCURRED ON A TILT-WING MULTIPROPELLER

VTOL/STOL AIRCRAFT OPERATING OVER A

LEVEL, GRAVEL-COVERED SURFACE

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DAMAGE INCURRED ON A TILT-WING MULTIPROPELLER VTOL/STOL AIRCRAFT OPERATING OVER A LEVEL, GRAVEL-COVERED SURFACE

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SUMMARY

A summary is presented of the damage experienced by a tilt-wing VTOL/STOL aircraft as a result of operating from a level surface covered with loose gravel. The damage was inadvertently incurred as the aircraft was performing a taxiing-turn maneuver over an area of level macadam surface containing loose and embedded crushed stone. Observers from a chase aircraft commented that the wing was tilted at approximately 76° with respect to the ground when the damage occurred. Deposits of stone in the open fuselage, punctures in the rotor blade skin, and damage to the compressor blades of the engine occurred due to the circulation of the crushed gravel.

INTRODUCTION

Helicopters in present military service have encountered serious difficulties when operating over unprepared areas. This difficulty is attributed to the circulation of debris, sand, and dust which affects aircraft ventilation, engine performance, visibility, and structural integrity.

Various military organizations which have encountered problems in helicopter operations over unprepared areas have adopted countermeasures affording partial relief from some of the problems. For example, filters have been installed on engine carburetors to reduce engine wear. However, aircraft maintenance is considerably increased (refs. 1 and 2). The general air-flow patterns about a low-disk-loading VTOL/STOL aircraft (helicopter) operating near the ground have been investigated by various companies and agencies, and it has been found that some relief can be afforded through the development of suitable operational procedures, although many problems remain (ref. 3).

Tests conducted by the NASA Langley Research Center to determine the conditions under which downwash from VTOL aircraft will start surface erosion from various types of terrain are reported in reference 4. The effects of ground proximity on the aerodynamic characteristics of a tilt-wing multipropeller VTOL aircraft model have also been studied (refs. 5 and 6). Actual information concerning operational experience, however, has generally been scarce.

The purpose of this paper is to give an account of the damage incurred by a tilt-wing VTOL aircraft during inadvertent operation from a level area covered with loose gravel.

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DESCRIPTION OF TEST EQUIPMENT AND SURFACE CONDITIONS

The test aircraft is a tilt-wing VTOL aircraft and is illustrated in figure 1. The two articulated rotors are driven by a single turbine engine. The wing tilts through 76° to achieve vertical lift-off and returns to a wing-down position for level flight. Pitching and yawing moments in hovering flight are entirely compensated for by a set of tail fans, one in the plane of the horizontal tail and one in the plane of the vertical tail, respectively. The two main rotors have a 0.070-inch-thick plywood skin, a metal leading edge, wooden ribs, and a metal trailing edge. Tail fans are constructed of laminated spruce with a bonded metal leading edge. The fuselage has thin sheet metal side covers, but is entirely open on the top and bottom. Further information on the characteristics of this aircraft may be found in reference 7 and in figure 2.

Figure 3 shows a general view of the 900-foot eastern overrun of a runway at Langley Air Force Base. Figure 4 shows the area over which the aircraft rolled and where the gravel concentration was the highest. This surface, as is shown in the closeup of figure 5, is macadam covered with a variety of loose and embedded crushed stone. This area of loose stone was approximately 600 square feet and 1/2 inch deep. Approximately 70 percent of the stones were 1/8 inch to 1/2 inch in diameter, and approximately 30 percent were 1/2 inch in diameter or larger.

TEST CIRCUMSTANCES

The aircraft, at the time of the maneuver that resulted in the damage under discussion, had completed a downwind landing following a test flight that was being observed by occupants of a helicopter serving as a chase aircraft. The pilot of the VTOL airplane was turning the aircraft in preparation for a return flight, when gravel from the overrun was thrown up through the rotors. According to observers in the chase helicopter, the wing was tilted at approximately 76° with respect to the ground. The engine was drawing 485 horsepower or approximately 80 percent of hovering power. At these conditions the disk loading was 19 lb/sq ft. The average downwash velocity behind the rotor was approximately 126 feet per second, as calculated from momentum considerations. Upon turning into the wind, the pilot took off with the wing tilted to 70° and flew the aircraft approximately 9,000 feet back down the runway. Comments from observers in the chase helicopter indicate that the damage was done to the aircraft as it turned after its downwind landing preparatory to an upwind take-off. The pilot reported that he noticed the sound of gravel on the bottom of the cockpit at this time but did not realize that it had reached the rotor blades.

SUMMARY OF DAMAGES

All rotating blades of the aircraft sustained some damage. The main rotor blades were at some angle of attack (approximately 6°) and the undersides of the blades showed the greater percentage of the damage. Figure 6 shows typical damage to the blades. This damage includes complete punctures of one side of the 0.070-inch-thick mahogany plywood skin on two blades, deep marring on all six blades, and peeling of the 0.008-inch-thick trailing-edge stiffener on one of the blades.

Serious gouging by flying stones marred the upper surfaces of the pitch fan (fig. 7) which was providing a downward thrust, and the right-hand surfaces of the yaw fan (fig. 8) which was providing thrust in the left-hand direction. The opposite surfaces showed relatively few scars except on the metal leading edge.

Preliminary inspection of the engine disclosed dirt over all exposed portions and nicks on the leading edges of several blades of the rotor and stator in the first stage. The engine was inspected by a factory representative and was then returned to the factory for overhaul.

Little damage was incurred by the aircraft itself, but the upwash through the uncovered fuselage structure deposited a great deal of dirt and small stones throughout the open fuselage and cockpit and necessitated a thorough cleaning. Examples of the particles found on and inside the aircraft are shown in figure 9. No damage could be found to external and uncovered bearings. The pilot indicated that he experienced no abnormal handling difficulties during the return flight after the damage had occurred.

GENERAL FLOW PHENOMENON

Careful inspection of the aircraft at the end of the flight presents evidence of the existence of a strong upwash at the fuselage at the time the damage was sustained. This deduction is primarily based on the handful of gravel that was found in the cockpit which could have entered only through holes in the floor. This type of flow has been previously noted in connection with tests of tilt-wing multipropeller VTOL aircraft models at the Langley Research Center, one such instance being discussed in reference 5. In the present case, the upward flow was noted in the region of the longitudinal plane of symmetry for the model without a fuselage. The addition of a typical transport-type fuselage altered the flow patterns somewhat; however, the upward flow tended to persist beneath the fuselage near the plane of symmetry. The large amount of dirt and small gravel deposited on all available resting places on the fuselage of the present VTOL aircraft further supports the presence of this upward flow. This general flow pattern is also illustrated in one sequence in the film supplement to reference 8, in which a model rotor is operated in ground effect near a model building. The vertical boundary formed by the side of the building essentially substitutes for a mirror image of the rotor. Thus the film sequence is generally representative of the type of flow induced by two lifting rotors operating near the ground and with some spacing of the rotor disks. The resulting flow pattern shows a strong upwash at the wall (which may be considered as the longitudinal symmetry plane) and corresponds to the type of flow believed responsible for the damage to the aircraft.

It would appear that the presence of this upwash must be given careful consideration in the design and operation of VTOL aircraft of the general configuration under discussion. As inferred from the film supplement of reference 8, operation of any static lifting system near an abrupt terrain feature, wall, solid fence, or the like, will tend to cause the same type of flow pattern, with the resulting possibility of circulating loose material through the lifting system. The shape and minimum size of objects or terrain features that will induce potentially hazardous flow patterns constitutes an area of needed research. The extent to which the upwash can be reduced by appropriate fuselage modifications should also be studied.

CONCLUDING REMARKS

A taxi-turning maneuver, performed by a tilt-wing VTOL aircraft after a downwind landing on a level macadam overrun covered with crushed stone in varying degrees of concentration, resulted in damage to the rotor blades and engine as a result of circulation of the gravel. Observers from a chase helicopter reported that the major damage occurred when the wing was at a tilt angle of 76° relative to the ground. The damage to the rotor blades ranged from multitudinous scars on all blades to complete punctures of the lower surface of the skin on two blades. Serious gouging of the surfaces of the tail fans and damage to the first stage of the engine were also found. These results clearly show that circulation of debris is a problem that needs careful consideration for aircraft with vertical take-off and landing capabilities.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., July 14, 1960.

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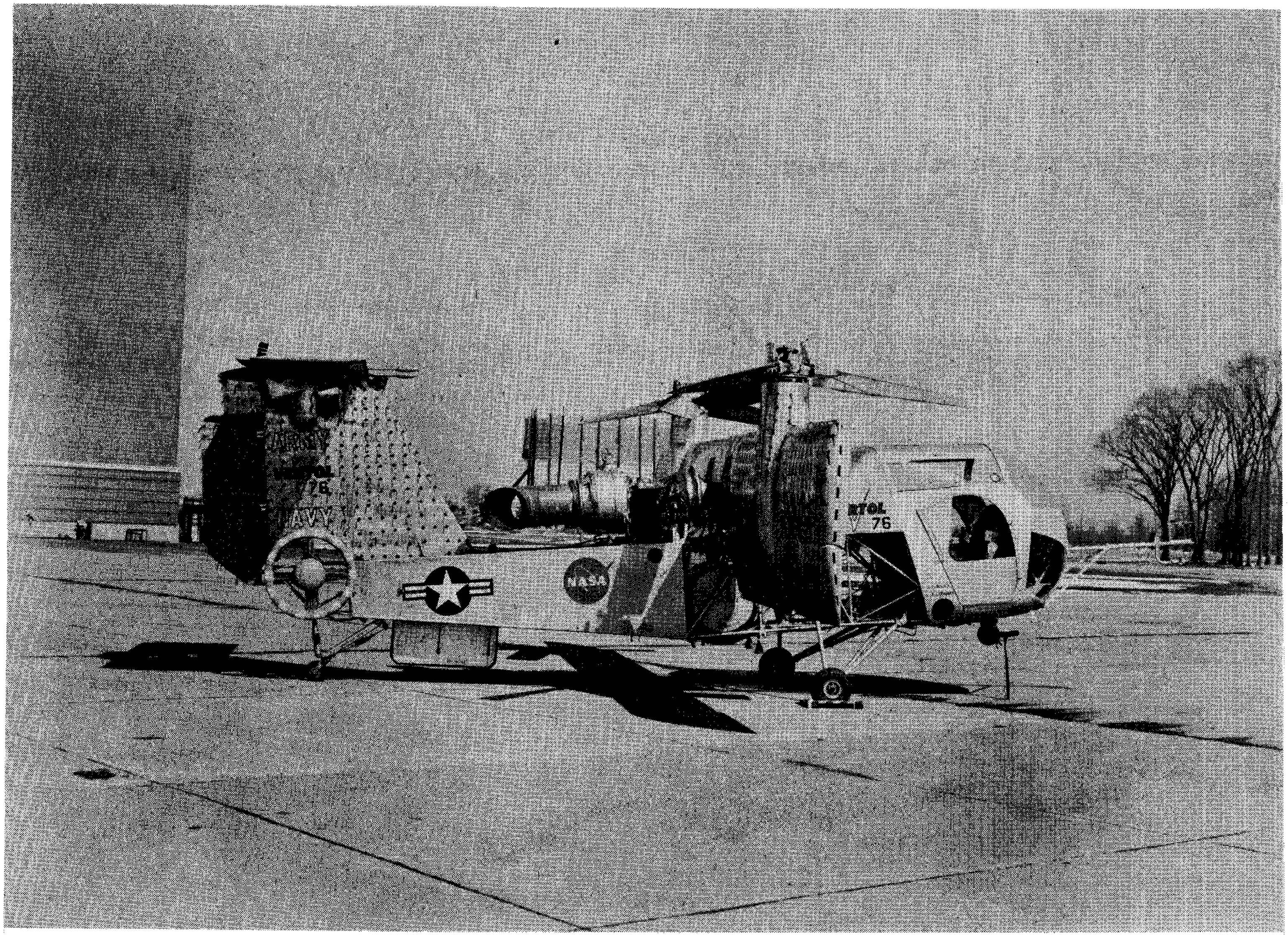

Figure 1.- General view. L-60-1328

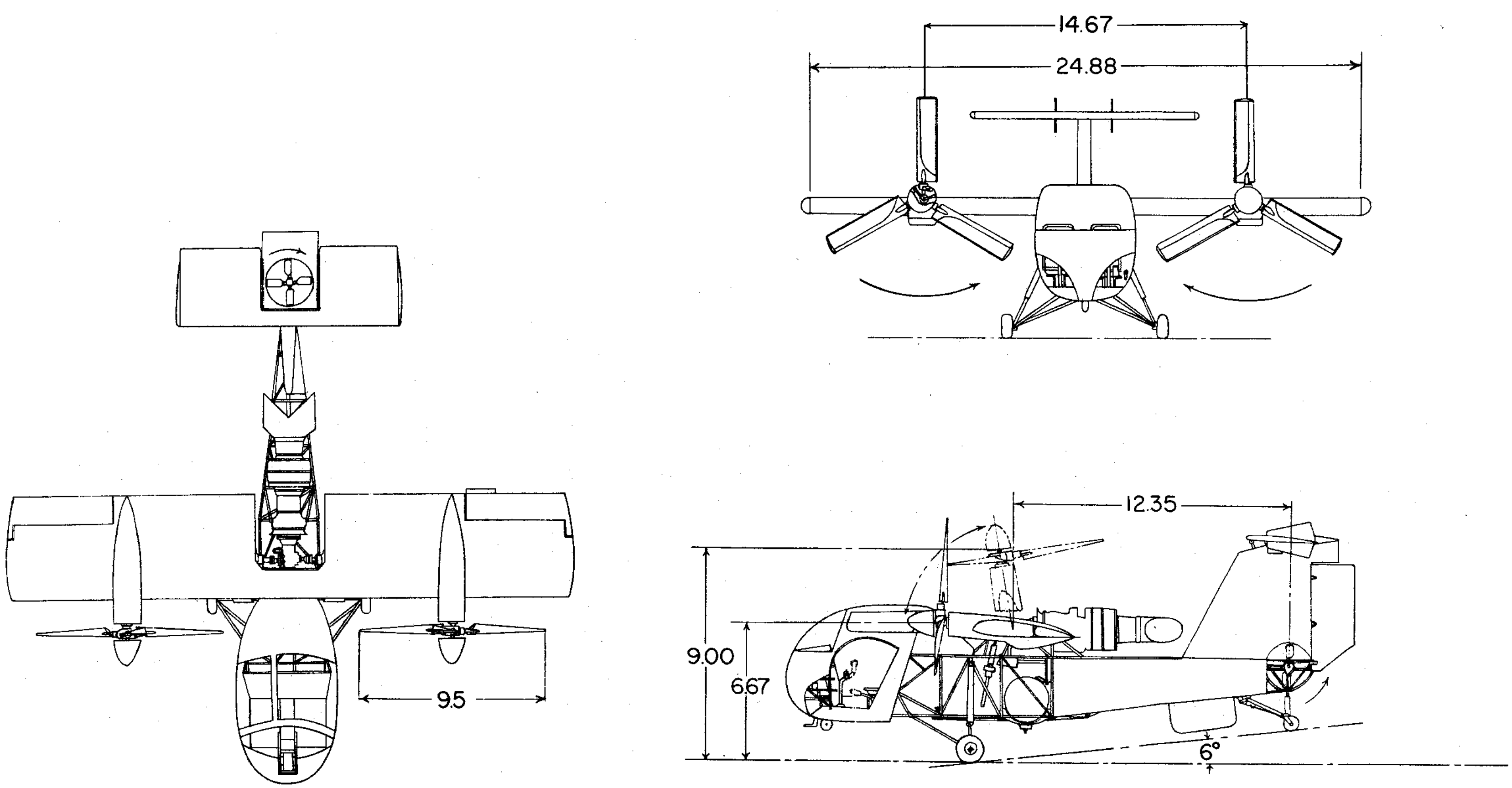

Figure 2.- Sketch of the tilt-wing VTOL aircraft. All dimensions are in feet, unless otherwise specified.

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Figure 3.- General view of overrun area. L-59-8143

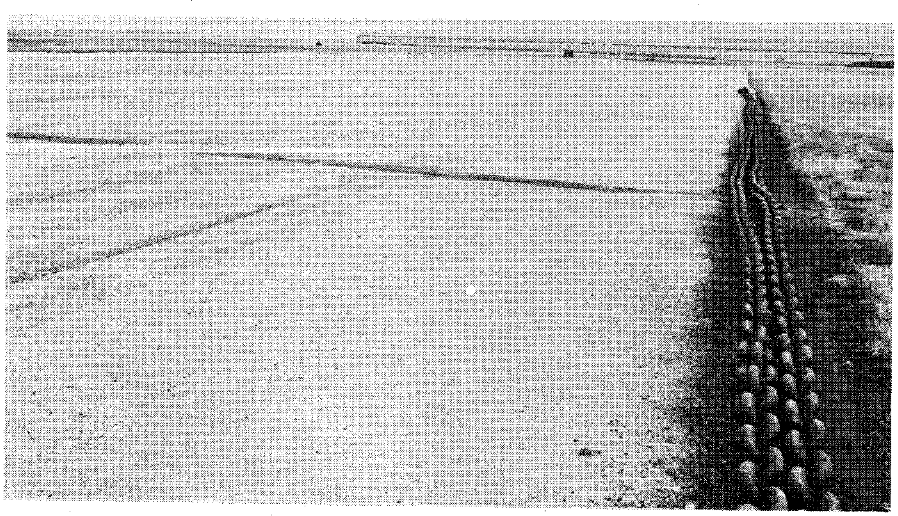

Figure 4.- Area of concentrated loose stone. L-59-8144

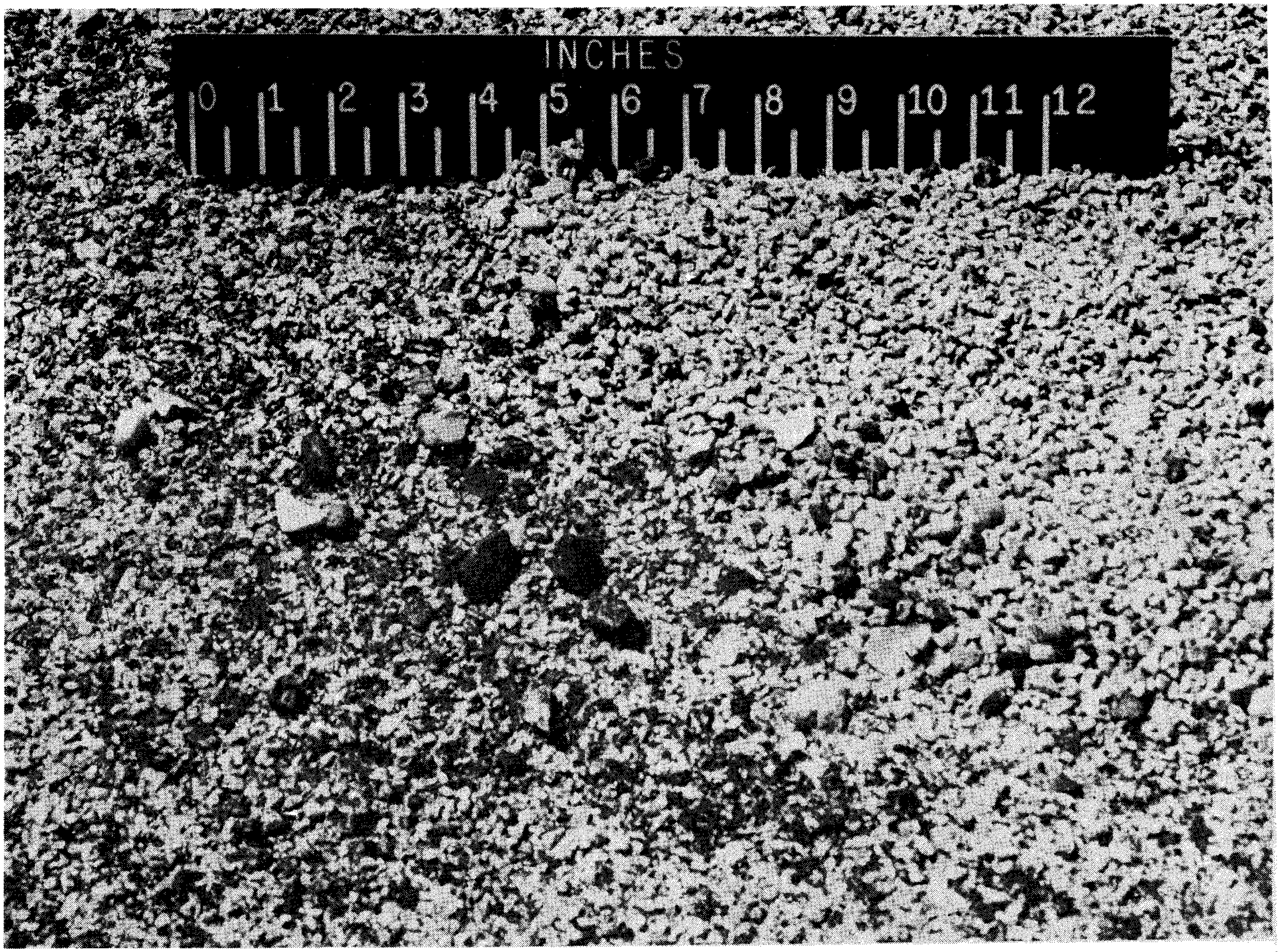

Figure 5.- Closeup of loose and embedded stone on overrun. L-60-4296

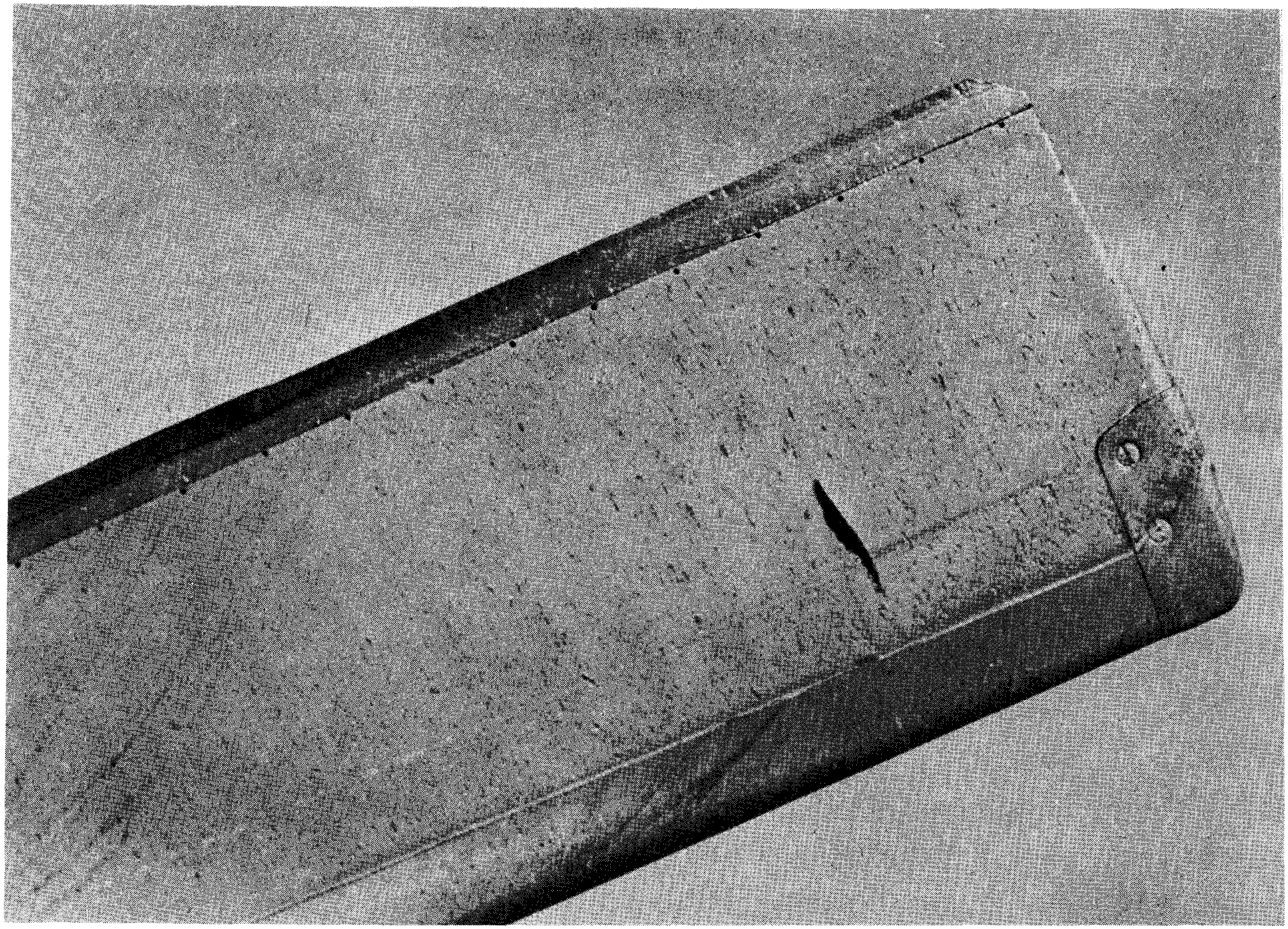

Figure 6.- Typical damage to main rotor blades. L-59-8139

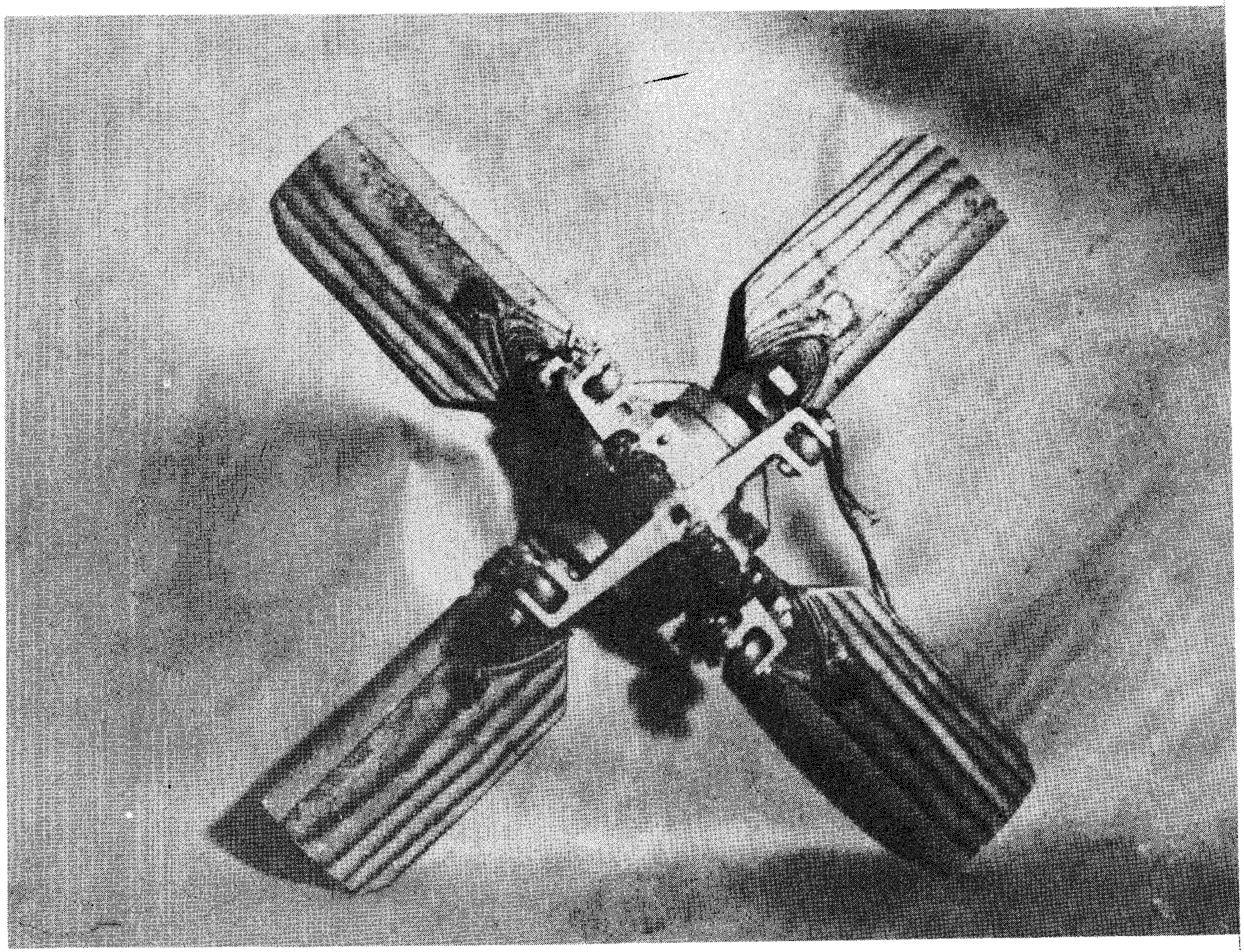

Figure 7.- Damage to pitch fan. L-60-4297

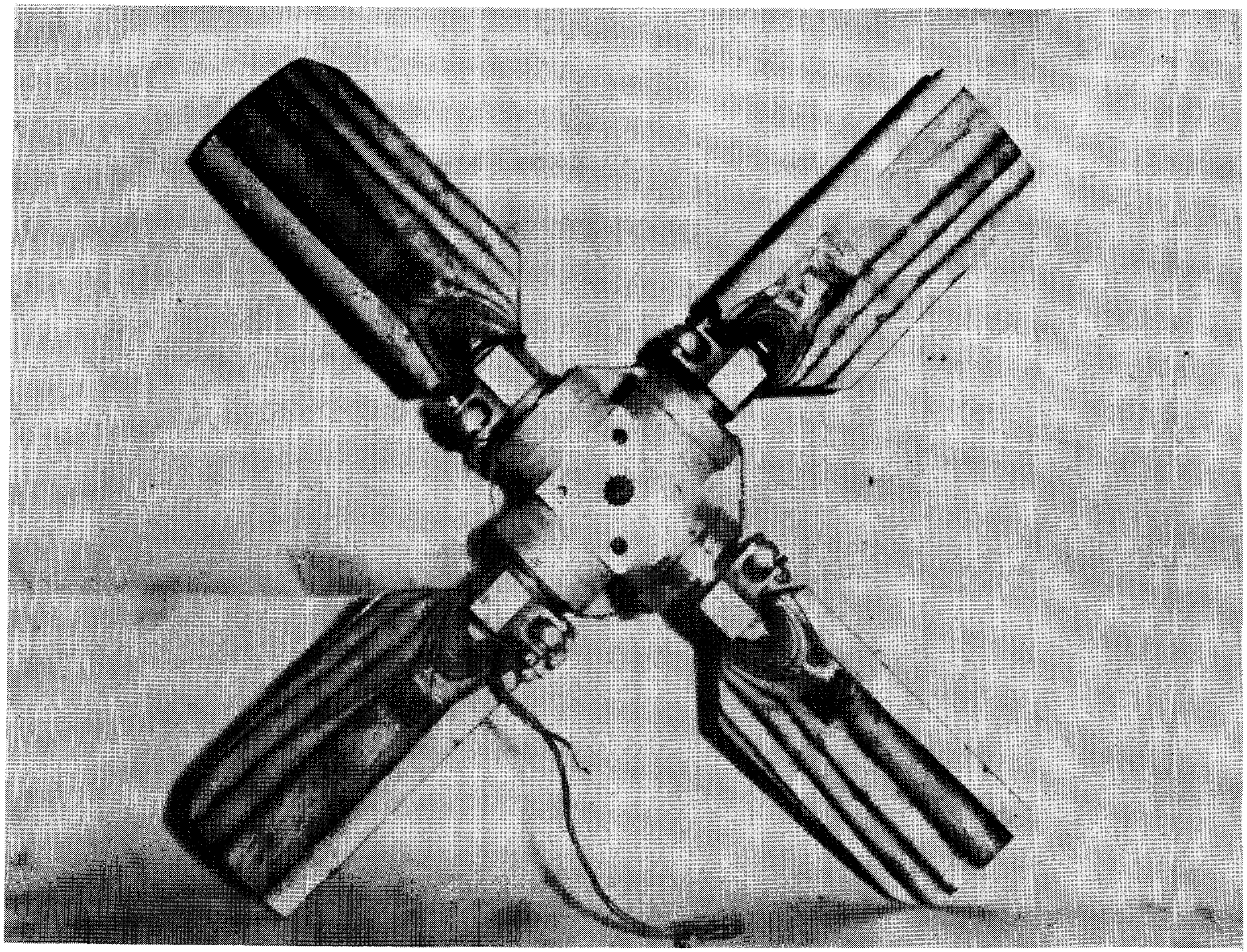

Figure 8.- Damage to yaw fan. L-60-4298

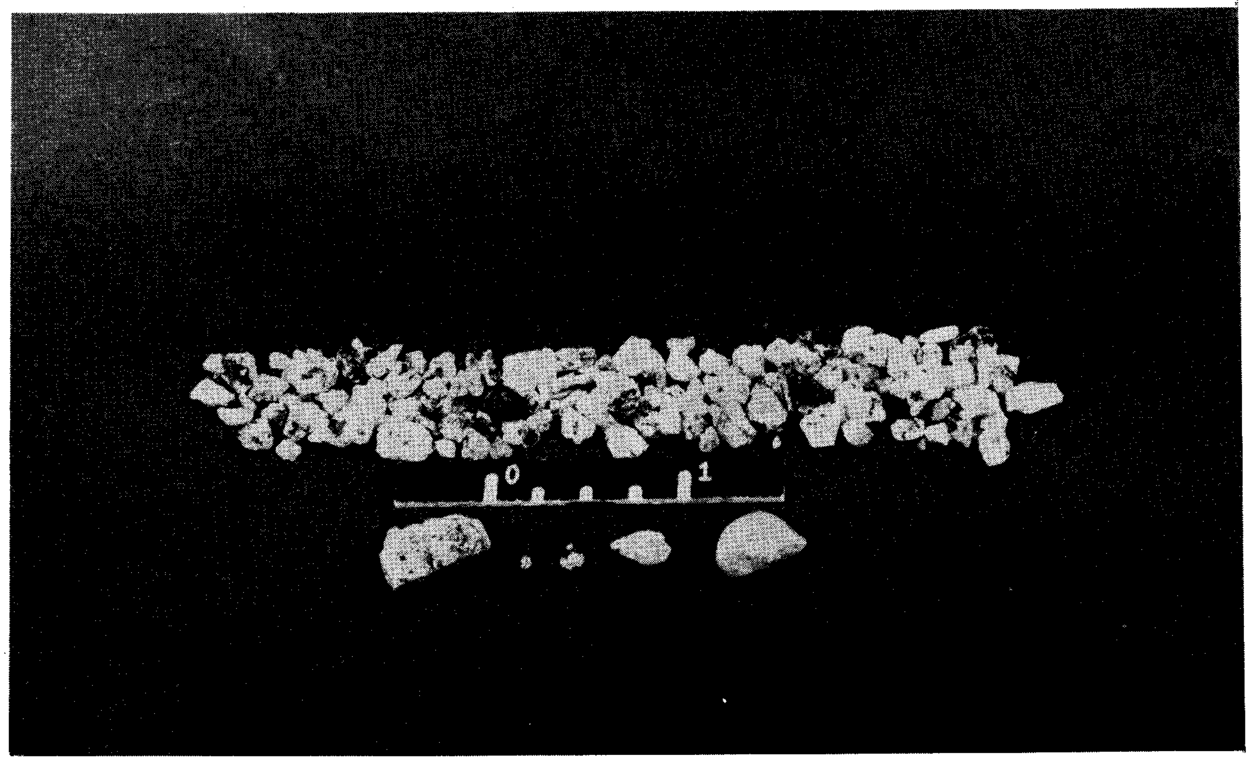

Figure 9.- Examples of stones found in fuselage. L-59-8146

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