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Developments in Pilot's Instructions for In-Flight Emergencies in Czechoslovak and Czech Republic Jet Combat Aircraft: Fire

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Abstract:

Fire on board an aircraft is one of the most serious incidents that may occur during operation. Ever since military jet combat aircraft were equipped with fire protection systems, flight manuals have included instructions to eliminate fire on board as part of the instructions for in-flight emergencies. Emergency abandonment thus was no longer the only and inevitable solution to the occurred situation. Over the sixty years of operation of military combat aircraft equipped with fire protection systems in Czechoslovakia and the Czech Republic, there has been a clearly discernible evolution also in instructing pilots in in-flight fire emergencies. These instructions reflect very well not only the progressive technical development of aircraft, but also the overall concept of safety in military aviation. This article presents a unique comprehensive overview of such emergency procedures, common features, differences and developments in Czechoslovak and Czech Republic military jet combat aircraft since 1951.

Keywords:

Army of the Czech Republic, Czechoslovak Army, Czechoslovak People's Army, pilot, instructions, jet combat aircraft, developments, in-flight emergencies

1. Introduction

Sixteen types of jet fighters in total of fifty-eight variants have served in the Czechoslovak and later the Czech Air Force over the past almost 70 years of its history. The series started already in 1948 with the Avia S-92 (original German name Messerschmitt Me-262 A) and has continued to the present with other types of aircraft.

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The complete list of jet fighter types and variants serving in the Air Force of Czechoslovakia and the Czech Republic can be found in [1].

Jet aircraft differed considerably from their propeller predecessors not only in construction design or aerodynamic characteristics, but also in flight performance, such as speed and ceiling. The concept of safety in aviation had to change, which was reflected in gradual deployment of various additional systems and safety elements. These systems and elements were designed to not only help the pilot to make full use of the technical capacity of the aircraft, but also to survive in emergency situations. Fire protection systems may serve as an example.

Fire protection systems, i.e. systems allowing on-board fire detection and fire extinguishing, appeared for the first time in jet fighters in Czechoslovakia in 1951 with the advent of the Soviet-manufactured Mikoyan-Gurevich MiG-15. Its two jet predecessors – the German Messerschmitt Me-262 A or B (Czechoslovak code name Avia S-92 or CS-92, respectively) and the Soviet Yakovlev Yak-23 (Czechoslovak code name S-101) had no fire protection system yet. As regards the risk of an in-flight fire, their operation was very dangerous compared to later jet aircraft types. Detailed information on fire protection systems in jet aircraft in Czechoslovakia and the Czech Republic can be found in [1].

With the deployment of fire protection systems in jet aircraft, a new entry – "Fire" – appeared in flight manuals, usually hidden in sections dedicated to pilot's operations in emergency situations.

It was a very important entry, as it reflected the level of knowledge and experience of that time, on which the pilot's chances of survival depended in emergency situations. The statistics available today of disasters, accidents and damages in early jet aircraft types indicate that the fire risk was not low at all, which is particularly true for the Mikoyan-Gurevich MiG-15 [1], the Mikoyan-Gurevich MiG-19 [2] and the Mikoyan-Gurevich MiG-21 [3].

The pilot's instructions for in-flight fire emergencies have undergone a distinct evolution since their origin and they reflect not only the technical progress of the different aircraft types, but also the evolution of the concept of safety in the Czechoslovak and later in the Czech military aviation. The following paragraphs are devoted to tracing trends, common features and differences and also to historical and technical contexts.

2. Pilot's Instructions for In-Flight Emergencies

In-flight emergencies are situations or incidents that do not occur during normal operation when all technical systems are fully functional and all compute modes in flight are complied with. However, they may occur when an aircraft is operated in a non-standard manner, as a result of a technical system failure or damage or with an unpredictable entry into one of the engine unit's non-compute modes. Examples of such emergencies include malfunction of flaps, malfunction of fuel pumps, engine stall or, last but not least, fire.

The brief description of the key content of the pilot's instructions for in-flight fire emergencies presented in the following paragraphs are arranged chronologically by the onset of the service of the given aircraft type in the Czechoslovak and then Czech Air Force.

An interesting remark related to the text below is that some of the pilot's instructions included the requirement to report the emergency situation to the air

traffic controller while other did not. The fact is now and was always in the past that all emergency situations must be reported to the air traffic controller regardless of whether it is stated in the manual. The duty to report the emergency is therefore not included in the following text. Variations in the instructions were usually due to the requirements of applicable standards under which the instructions were drawn up.

2.1. The Mikoyan-Gurevich MiG-15

The Mikoyan-Gurevich MiG-15 operated in the Air Force of the Czechoslovak Army (hereinafter "ČSA") and Czechoslovak People's Army (hereinafter "ČSLA") in ten variants from 1951 to 1983. The flight manuals used for this study date from 1952, 1954 and 1963 [5 – 7]. The only aircraft component actively protected against fire was the engine. The operations were described in Czech mostly in full sentences; occasionally, short comments were included as a bulleted list. In contrast to the Russian original, no graphical inserts were present.

The pilot's instructions covered only the event of an in-flight fire. If a fire started in the engine compartment, a red warning light located on the left panel in the cockpit illuminated. To extinguish the fire, the pilot had to close the closing and fuel fire valve, switch off suction and fuel transfer pumps, reduce the flight speed to 300 – 350 km/h and press the fire-extinguishing system button labeled "Extinguishant" or, in original Soviet aircraft, "Огнетушитель" ("Fire Extinguisher"). It was forbidden to restart the engine after extinguishing the fire and a forced landing or ejection ensued. The instructions did not contain more information.

2.2. The Mikoyan-Gurevich MiG-17

The Mikoyan-Gurevich MiG-17 operated in the ČSLA Air Force in two variants from 1955 to 1968. The only flight manual which was found and used for this study dates from 1955 [7]. The only aircraft component actively protected against fire was the engine. The operations were described mostly in full sentences; occasionally, short comments were included as a bulleted list; no graphical inserts were present.

The pilot's instructions covered only the event of an in-flight fire. The procedures to identify and extinguish a fire were identical to those for MiG-15.

2.3. The Ilyushin Il-28

The Ilyushin Il-28 operated in the ČSLA Air Force in four variants from 1955 to 1973. The flight manuals used for this study date from 1951, 1955, 1958 and 1972 [9 – 11]. The aircraft components actively protected against fire were both the engine units and four out of five fuel tanks. The operations in Czech language were described mostly in full sentences; occasionally, short comments were included as a bulleted list. No graphical inserts were present in contrast to the Russian original with generous graphics [10].

The pilot's instructions covered only the event of an in-flight fire. If a fire started, red warning lights located on the left panel in the cockpit illuminated indicating fire in the left or right engine, or in forward or aft fuel tanks. To extinguish the fire, the pilot had to close the closing and fuel fire valve, reduce the flight speed to 300–350 km/h and press the button to activate the fire-extinguishing system for the affected engine unit or fuel tank. It was forbidden to restart the engine after extinguishing the fire and a forced landing or ejection ensued. For cases of shot perforations or other defects in the fuel tank associated with a fire risk, the aircraft was equipped with the "inner gas

system" that ensured that constant overpressure of a neutral gas (carbon dioxide) distributed from a pressure bottle was kept above the fuel surface.

2.4. The Mikoyan-Gurevich MiG-19

The Mikoyan-Gurevich MiG-19 operated in the ČSLA Air Force in four variants from 1958 to 1972. The only found flight manual used for this study dates from 1961 [11]. The only aircraft components actively protected against fire were the engines. However, in the cockpit there was no indicator to inform the pilot of which of the two engines was on fire. The operations in Czech language were described mostly in full sentences; occasionally, short comments were included as a bulleted list; no graphical inserts were present.

The pilot's instructions covered only the event of an in-flight fire. If a fire started in the engine compartment, a red warning light located on the left panel in the cockpit illuminated. As the aircraft was twin-engined and there was no system to identify which engine was burning, two scenarios of emergency procedures were defined in the pilot's instructions guide. The first scenario assumed that the pilot was able to identify which engine was on fire. The second scenario assumed that such identification was not possible.

Under the first scenario, the pilot had to determine which engine was burning, either visually or by reference to control instruments and responses of engine units. Then he had to shift the respective control lever to "stop" position, press the fuel shut-off valve button and finally press the fire-extinguishing system button labeled "Fire Extinguisher" (original label in Russian "Огнетушитель"). It was forbidden to restart the engine after extinguishing the fire and a forced landing or ejection ensued. Under the second scenario, the pilot had to shift control levers for both engines to "stop" position, switch off all booster and fuel transfer pumps, press the fuel shut-off valve buttons for both engines, and finally press the fire-extinguishing system button. It was forbidden to restart the engines after extinguishing the fire and an ejection ensued. Safe landing with no working engine was not possible.

2.5. The Mikoyan-Gurevich MiG-21

The Mikoyan-Gurevich MiG-21 operated in the Air Force of the ČSLA, ČSA and the Army of the Czech Republic (hereinafter "AČR") in ten variants from 1961 to 2005. The flight manuals used for this study date from 1966, 1967, 1974, 1975, 1976, 1977 and 1992 [13 – 19]. The only aircraft component actively protected against fire was the engine. The operations were described mostly in full sentences; occasionally, short comments were included as a bulleted list; no graphical inserts were present. Abbreviations began to be used, such as POM (for "engine control lever") or SORC (for "centralized signalization of dangerous modes", original Russian abbreviation "СОРЦ" for "Систем Цэнтрализованной Сигнализации Опасных Режимов"). The content of the pilot's instructions gradually augmented over time. The early pilot's instructions from the 1960s covered only the event of an in-flight fire [13, 14]. In the 1970s, the instructions extended to events of a fire during takeoff and liftoff [15, 16] and also during take-off run [17, 18]. In the 1990s, the move towards re-simplification and universality of the procedures is apparent [18].

If a fire started in the engine compartment, a red warning light labeled "Fire" located on the panel in the cockpit illuminated. From the late 1970s onwards, the aircraft was furnished with SORC button light that in later variants of the aircraft the

pilot had to press during visual check to confirm that he was aware of the emergency situation. The sequence and number of operations during an in-flight fire was slightly changed and refined for different versions of the MiG-21. Generally, the pilot had to reduce the engine speed to idle, reduce the airspeed below 500 km/h (400 – 450 km/h in the MiG-21U), activate the fire-extinguishing system, disengage the autopilot, use the oxygen supply for breathing and perform ejection or a forced landing with the engine off. It was forbidden to restart the engine after extinguishing the fire.

In case of a fire in the engine compartment during takeoff and liftoff, the pilot had to continue taking off, activate the fire-extinguishing system with the button labeled "Fire Extinguisher" (original label in Russian "Огнетушитель"), retract the landing gear, retract flaps, at a safe airspeed climb to an altitude safe for ejection and proceed as the situation required.

In case of a fire in the engine compartment during take-off run, the pilot had to discontinue the take-off procedure immediately, shut off the engine, take measures to stop the aircraft, activate the fire-extinguishing system, switch off booster pumps and fuel transfer pumps and abandon the aircraft immediately after it came to a halt. If the aircraft should roll off the runway and there was a danger of collision with an obstacle, it was recommended to retract the landing gear.

2.6. The Aero L-29 Delfin

The Aero L-29 Delfin operated in the ČSLA, ČSA and AČR Air Force in three variants from 1963 to 2003. The only found flight manual used for this study dates from 1964 [19]. The only aircraft component actively protected against fire was the engine. The operations were described mostly in full sentences; occasionally, short comments were included as a bulleted list; no graphical inserts were present.

If a fire started in the engine compartment during flight, a red warning light labeled "Fire" located on the panel illuminated. If the pilot ruled out malfunction of the signaling system and concluded that a fire arose, he had to place the throttle lever to "shut-off" position, close the fuel shut-off valve, reduce the airspeed to 240 km/h, activate the fire-extinguishing system and depending on the situation perform ejection or a forced landing with the engine off. It was forbidden to restart the engine after extinguishing the fire.

2.7. The Sukhoi Su-7

The Sukhoi Su-7 operated in the ČSLA Air Force in three variants from 1964 to 1990. The flight manuals used for this study date from 1964, 1967 and 1969 [21 – 23]. The only aircraft component actively protected against fire was the engine. The operations in Czech language were described mostly in full sentences; occasionally, short comments were included as a bulleted list; no graphical inserts were present. The content of the pilot's instructions did not change over time.

If a fire started in the engine compartment during flight, a red warning light labeled "Fire" located on the panel illuminated. Other signs of a fire included a smoke trail behind the aircraft visible in turns, increased fuel consumption, illumination of the signal light labeled "Fuel pressure" (original label in Russian "Давление топлива") or a pressure drop in the hydraulic system manifested by a change in control forces and thus by a change in airplane handling characteristics. In the first phase, the pilot had to climb to an altitude safe for ejection, turn off the afterburner if it was on and check if there was a smoke trail behind the aircraft by making a turn. If

yes, ejection was prescribed in altitudes below 3000 m. In altitudes above 3000 m, the pilot had to place the throttle lever to "stop" position, close the fuel fire valve, reduce the airspeed below 700 km/h (in early versions of the aircraft equipped with the Ljulka AL-7F-1-100 engine to 350 – 400 km/h) due to the efficiency of the fire-extinguishing system, switch off booster pumps and fuel transfer pumps, activate the fire-extinguishing system, and if the fire persisted, eject. It was forbidden to restart the engine after extinguishing the fire.

2.8. The Aero L-39 Albatros

The Aero L-39 Albatros has operated in the ČSLA, ČSA and then AČR Air Force in four versions since 1971. The flight manuals used for this study date from 1982 and 2008 [24, 25]. The only aircraft component actively protected against fire is the engine. The operations in Czech or English are described in rather short comments as a numbered list with many English abbreviations; no graphical inserts are present. The pilot's instructions cover engine fire in flight, fire when starting the engine and fire during takeoff.

If a fire starts in the engine compartment, a red signal light labeled "Fire" located on the left warning panel in the cockpit illuminates. Other signs of fire include fumes in the cockpit, a smoke trail behind the aircraft or a sudden increase of the exhaust gas temperature at a steady flight mode.

If a fire starts in the engine compartment in flight, the pilot has to place the throttle lever to "idle" position. If the fire warning light goes out, he has to check the fire warning system. If no evidence confirms the fire, the signs must be continuously monitored and a landing performed as soon as possible. If the fire is confirmed, the cockpit pressurization has to be shut off, the oxygen supply delivered and the cockpit air shower closed. If there are conditions for a forced landing, the throttle lever has to be placed to "stop" position, the fuel supply to the engine closed and the pilot has to press the fire-extinguishing system button. If the fire indication goes out, it is required to check the fire signaling system and perform a forced landing. It is forbidden to land with a fire aboard or to use the "Roll-Stop" system (an emergency system to capture excess kinetic energy of an aircraft at the end of runway). If the fire persists, an ejection must be performed.

If a fire starts in the engine compartment during takeoff, the pilot has to abort the takeoff, if possible, close the fuel supply to the engine, press the fire-extinguishing system button, switch off the battery and perform emergency evacuation. If takeoff cannot be aborted, he has to place the throttle lever to "max" position, retract the landing gear, jettison weaponry from hardpoints and continue climbing while creating conditions for a forced landing. Before performing a forced landing, the pilot has to place the throttle lever to "stop" position, close the fuel supply to the engine and press the fire-extinguishing system button. If a safe forced landing is not possible, he has to eject.

If a fire starts in the engine compartment when starting the engine on the ground, the pilot has to place the throttle lever to "stop" position, switch off the engine and close the fuel supply to the engine. If the fire persists, he has to press the fire-extinguishing system button and abandon the aircraft immediately. After the fire has been extinguished, the engine must not be restarted.

2.9. The Mikoyan-Gurevich MiG-23

The Mikoyan-Gurevich MiG-23 operated in the ČSLA, ČSA and AČR Air Force in four variants from 1978 to 1998. The flight manuals used for this study date from 1979 and 1998 [26, 27]. The only aircraft component actively protected against fire was the engine. The operations in Czech were described mostly in rather short comments as a bulleted list, rarely in full sentences. No graphical inserts were present. Occasionally, abbreviations were used, such as SORC or SAU (for "automatic control system"; original Russian abbreviation "САУ" for "Система Автоматического Управления"). In terms of pilot's instructions content, for the first time the indication of a fire included a piece of voice information "Engine fire", transmitted into the pilot's headset. The pilot's instructions covered fire in flight, fire before liftoff at the end of the runway and fire in the first half of the take-off run.

If a fire started in the engine compartment, a red signal light labeled "Fire" located on the warning panel in the cockpit illuminated and the SORC light button started to flash. Voice information "Engine fire" spoken in Russian was transmitted into the pilot's headset repeatedly until the pilot began to address the existing emergency situation. The voice warning system was popularly called "Natasha" among pilots as the voice used was usually a female voice. Other signs of a fire included fumes in the cockpit, a smoke trail behind the aircraft, a pressure drop in the hydraulic systems, control malfunction or a change in the behavior of the aircraft. The sequence and number of operations during a fire in flight slightly changed and refined for different versions of the MiG-23.

In the earlier MiG-23BN variant, if a fire started in the engine compartment in flight, the pilot had to turn off the afterburner if it was on, activate the fire-extinguishing system, reduce the airspeed to 500 km/h, use the oxygen supply for breathing, shut off the cockpit pressurization valve, and turn off SAU. Then, depending on the situation, he had to eject or perform a forced landing with the engine off [25]. In the later MiG-23ML variant, for the same case, it was prescribed to turn off the afterburner, create conditions for ejection, activate the fire-extinguishing system and eject immediately (shut off the engine, if possible) [26].

If a fire started in the engine compartment before liftoff at the end of the runway, the pilot had to continue taking off, activate the fire-extinguishing system, retract the landing gear, retract flaps (after reaching the minimum altitude of at least 100 m and the minimum airspeed of at least 400 km/h), at a safe airspeed climb to an altitude safe for ejection and then eject immediately.

If a fire started in the engine compartment in the first half of the take-off run, the pilot had to abort the takeoff immediately, shut off the engine, decelerate the aircraft, close the fuel shut-off valve, activate the fire-extinguishing system, switch off supply and fuel transfer pumps and abandon the aircraft immediately after the aircraft stopped. If the aircraft should roll off the runway and there was a danger of collision with an obstacle, it was prescribed to retract the landing gear if the aircraft's speed was less than 130 km/h or to eject if it exceeded 130 km/h [25]. The instruction for the MiG-23ML variant was supplemented by electrical circuit switch-off and the speed limit for ejection was changed to 140 km/h [26].

2.10. The Sukhoi Su-22

The Sukhoi Su-22 operated in the ČSLA, ČSA and AČR Air Force in two variants from 1984 to 2002. The flight manuals used for this study date from 1987 and 1989

[28, 29]. The only aircraft component actively protected against fire was the engine. The operations in Czech were described mostly in rather short comments as a bulleted list, rarely in full sentences; no graphical inserts were present. The pilot's instructions covered fire in flight, during takeoff before lifting off and during the take-off run.

If a fire started in the engine compartment, a warning light labeled “See panel” (original label in Russian “Смотри табло”) flashed on the instrument panel in the cockpit and a warning lamp labeled “Fire” (original Russian label “Пожар”) illuminated. Other signs of a fire included fumes in the cockpit, a smoke trail behind the aircraft, a pressure drop in the hydraulic systems, control malfunction or a change in the behavior of the aircraft, increased fuel consumption or illuminated warning lamps labeled “T°DVIGAT” (original Russian label “T^{0}ДВИГАТ”) for exceeding the permitted exhaust gas temperature and “PODKAČKI NET” (original Russian label “ПОДКАЧКИ НЭТ”) for malfunction of both fuel supply pumps.

If a fire started in the engine compartment, the pilot had to turn off the afterburner if it was on, reduce the engine speed to minimum that allowed the flight to continue, reduce the airspeed below 700 km/h and activate the fire-extinguishing system with the button labeled “Engine fire” (original Russian label “Пожар двигателя”). If fumes appeared in the cockpit, the pilot had to close the valves for garment pressurization and ventilation and use the oxygen supply for breathing. If the fire persisted, he had to release loads from hardpoints, shut off the engine and eject. If the fire was extinguished, the pilot was allowed to land at the closest airfield according to the air traffic controller's instructions while being prepared for ejection at any time.

If a fire started in the engine compartment before liftoff at the end of the runway (it was not possible to abort the takeoff safely or to eject), the pilot had to activate the fire-extinguishing system with the button labeled “Engine fire” and continue taking off. If fumes appeared in the cockpit, the pilot had to close the valves for garment pressurization and ventilation and use the oxygen supply for breathing. After a safe altitude, position and airspeed had been reached, it was prescribed to eject or, if the fire had been successfully extinguished, to make an emergency landing.

If a fire started in the engine compartment during the take-off run, the pilot had to abort the takeoff immediately, shut off the engine, decelerate the aircraft by whatever means, close the fuel fire valve and activate the fire-extinguishing system with the button labeled “Engine fire”. If fumes appeared in the cockpit, the pilot had to close the valves for garment pressurization and ventilation, use the oxygen supply for breathing and abandon the aircraft immediately after the aircraft stopped. If the aircraft should roll off the runway and there was a danger of collision with an obstacle, it was prescribed to switch off the electrical circuit and retract the landing gear if the aircraft's speed was less than 75 km/h. If the aircraft's speed exceeded 75 km/h, ejection ensued [28, 29].

2.11. The Sukhoi Su-25

The Sukhoi Su-25 operated in the ČSLA, ČSA and AČR Air Force in two variants from 1984 to 2000. The flight manuals used for this study date from 1987 and 1991 [30, 31]. The only aircraft components actively protected against fire were the two engines. The operations in Czech language were described mostly in rather short comments as a bulleted list, rarely in full sentences. Exceptionally, graphical inserts were present (only for the Su-25UBK [30]). The pilot's instructions in the 1987 flight manual for the Su-25K covered fire in flight only [29]. The 1991 flight manual for the

Su-25UBK covered also fire during the take-off run, fire on the flight line, fire after the engine start, during taxiing and after landing [30].

If a fire started in the engine compartment, a warning light labeled "See panel" (original label in Russian "Смотри табло") flashed on the instrument panel in the cockpit, a warning lamp labeled "Fire" (original Russian label "Пожар") illuminated and a red warning light labeled "Left engine fire" (original Russian label "Пожар лев. дв.") or "Right engine fire" (original Russian label "Пожар прав. дв.") illuminated. Other signs of a fire included fumes in the cockpit, a smoke trail behind the aircraft, a pressure drop in the hydraulic systems, control malfunction or a change in the behavior of the aircraft.

In the Su-25K, if a fire started in the engine compartment in flight, the pilot had to shut off the engine, close the fuel fire valve for the burning engine, use the oxygen supply for breathing and switch off the air conditioning if fumes appeared in the cockpit, and activate the fire-extinguishing system by pressing the button for extinguisher no. 1. If the fire was extinguished, it was necessary to suspend the mission and land at the closest airfield. If the fire was not extinguished, the pilot pressed the button for extinguisher no. 2. If the fire still persisted, it was prescribed to eject [29]. In the Su-25UBK, the procedure differed slightly in that the buttons for the extinguishers no. 1 and no. 2 were pressed simultaneously right away and generators for the burning engine were shut off [30]. It was forbidden to restart the engine after extinguishing the fire, but it was possible to land safely with only one working engine.

If a fire started in the engine compartment during the take-off run, the pilot had to abort the takeoff immediately, shut off the engine, halt the aircraft, close the fuel fire valve, press the buttons for no. 1 and no. 2 extinguishers simultaneously, switch off the electrical circuit after the engine stopped and abandon the aircraft. If the fire was not extinguished, ejection was possible if the aircraft's speed exceeded 100 km/h. If the speed was less than 100 km/h, it was necessary to jettison the canopy, retract the landing gear after runway excursion and switch off the electrical circuit. Right before lifting off when the takeoff could not be aborted, it was prescribed to continue taking off and eject afterwards when the conditions for ejection were appropriate.

If a fire started in the engine compartment on the flight line, after the engine start, during taxiing or after landing, the pilot had to shut off both engines, close the fuel fire valve for the burning engine, simultaneously press the buttons for no. 1 and no. 2 extinguishers for the burning engine, switch off the electrical circuit and abandon the aircraft immediately.

2.12. The Mikoyan-Gurevich MiG-29

The Mikoyan-Gurevich MiG-29 operated in the ČSLA, ČSA and AČR Air Force in two variants from 1989 to 1994. The flight manuals used for this study date from 1990 and 1991[32, 33]. The aircraft components actively protected against fire were the two engines and the aircraft accessory gearbox "KSA" (original Russian label "КСА" and description "Коробка Самолетных Агрегатов"). The operations in Czech were described exclusively in rather short comments as a bulleted list. The pilot's instructions covered fire in flight, fire after liftoff, during the take-off run before lifting off, on the flight line and during taxiing.

If a fire started in the engine compartment or in the accessory gearbox, a warning light button labeled "KSC" (for "centralized signalization of dangerous modes"; original Russian label "КСЦ" and description "Кнопка-лампа Сигнализации

опасных режимов Централизованная") flashed, a warning lamp labeled "Left engine fire" (original Russiän label "Пожар лев.") or "Right engine fire" (original Russian label "Пожар прав.") or "KSA" ("Accessory gearbox fire"; original Russian label "Пожар КСА") illuminated on the panel, voice information "Left/Right engine fire" or "Accesory gearbox fire" spoken in Russian was transmitted into the pilot's headset repeatedly until the pilot started to address the existing emergency situation. Other signs of a fire included fumes in the cockpit, a smoke trail behind the aircraft or flames behind the aircraft.

If a fire started in the engine compartment in flight, the pilot had to turn off the afterburner, shut off the burning engine, close the fuel supply for the burning engine, disengage the autopilot SAU and activate the fire extinguisher for the burning engine by toggling the switch labeled "Fire extinguisher" (original Russian label "Огнетушитель") to "Left" (original Russian label "Лев.") or "Right" (original Russian label "Прав.") position. If the fire persisted, the pilot had to shut off both engines end eject. If the fire was extinguished, it was possible to make an emergency single engine landing, taking into consideration possible ejection at any time.

If a fire started in the accessory gearbox in flight, the pilot had to turn off the afterburner if it was on, activate the fire extinguisher for the burning engine by toggling the switch labeled "Fire extinguisher" (original Russian label "Огнетушитель") to "KSA" position. If the fire persisted, the pilot had to shut off both engines and eject. If the fire was extinguished, it was prescribed to land immediately.

If a fire started in the engine compartment after liftoff, the pilot had to continue taking off, activate the corresponding fire extinguisher (see above), climb to an altitude safe for ejection, shut off the burning engine and close the fuel fire valve for the burning engine. If the fire persisted, he had to shut off both engines and eject. If the fire was extinguished, it was possible to make an emergency single engine landing, taking into consideration possible ejection at any time.

If a fire started in the accessory gearbox after liftoff, the pilot had to continue taking off, activate the fire extinguisher for the accessory gearbox (see above) and climb to an altitude safe for ejection. If the fire persisted, the pilot had to shut off both engines and eject. If the fire was extinguished, it was prescribed to land immediately.

If a fire started in the engine compartment or in the accessory gearbox during the take-off run before lift-off, the pilot had to shut off both engines, halt the aircraft, close the fuel fire valves, activate the fire extinguisher for the burning segment of the aircraft and abandon the aircraft immediately after it came to a halt. If the aircraft should roll off the runway and there was a danger of collision with an obstacle, it was prescribed to switch off the electrical circuit and, if the aircraft's speed was less than 70 km/h, retract the landing gear. If the aircraft's speed exceeded 70 km/h, it was prescribed to eject [31]. For the MiG-29UB variant the speed limit for ejection was changed to 150 km/h [32].

If a fire started in the engine compartment or in the accessory gearbox on the flight line or during taxiing, the pilot had to shut off both engines, brake the aircraft, close the fuel fire valve for the burning engine, activate the corresponding fire extinguisher for the burning segment of the aircraft and abandon the aircraft once it came to a halt.

2.13. The Aero L-159 Alca

The Aero L-159 ALCA (English abbreviation for "Advanced Light Combat Aircraft") has operated in the AČR Air Force in two variants since 1999. The only found flight manual used for this study dates from 2004 [33]. The only aircraft component actively protected against fire is the engine. The operations in Czech or English are described in rather short comments as a numbered list with many English abbreviations. No graphical inserts are present. The pilot's instructions cover engine fire in flight, engine fire during takeoff and engine fire when starting up on the ground.

If a fire starts in the engine compartment, a MASTER CAUTION warning signal illuminates in the cockpit and on the head-up display (HUD) a WARN indication is displayed. At the same time, on the multi-function display (MFD) an ENG FIRE indication is displayed and the same ENG FIRE indication is also displayed on the left warning panel. Other signs of a fire include fumes in the cockpit, a smoke trail behind the aircraft, flames behind the aircraft, unusual engine noise or excessive vibration.

If a fire starts in the engine compartment in flight, the pilot has to place the engine control lever to idle position, climb to an altitude safe for ejection or emergency landing planning and verify on the MFD if the fire indication is correct. If no evidence confirms the fire, the signs must be continuously monitored and a landing performed as soon as possible. If the fire is confirmed, it is necessary to shut off the engine immediately, close the fuel supply to the engine, activate the fire extinguisher and observe the fire warning indicator. If the fire is extinguished, the pilot may attempt to make an emergency landing with the engine off. It is not recommended to restart the engine after extinguishing a fire, but the final decision is always up to the pilot. If the fire persists or conditions for an emergency landing cannot be created, it is prescribed to eject. Before an emergency landing is performed, it is necessary to launch or jettison the ammunition from hardpoints and jettison the additional fuel tanks, if they are not completely empty. Conversely, completely empty fuel tanks can be used to absorb part of the aircraft's energy when touching the ground. They can thus serve as an additional deformation zone of the fuselage or wings. There is no more danger these external fuel tanks would ignite because after emptying they are sufficiently blown through by compressed air.

If a fire starts in the engine compartment during takeoff, the pilot has to apply the same common procedure as in the case of a fire in flight. If the takeoff can be aborted, the pilot has to abandon the aircraft once it comes to a halt even if the fire was extinguished because of the danger of reignition. If the takeoff cannot be aborted, there are not conditions for an emergency landing or the fire reignited, ejection is prescribed.

If a fire starts in the engine compartment when starting up the engine on the ground, the pilot has to apply the same common procedure as in the case of a fire during takeoff (see above) when the takeoff can be aborted.

2.14. The Saab JAS-39 Gripen

The Saab JAS-39 Gripen has operated in the AČR Air Force in two variants since 2005. The only aircraft component actively protected against fire is the auxiliary power unit (APU). The operations are described mostly briefly as a numbered list with many English abbreviations and no graphical inserts. The pilot's instructions in general cover fire in the engine compartment, fire or high temperature in the APU and smoke in the cockpit.

The fire warning and fire suppression procedure is four-staged (i.e. fire warning – verification – fire extinguishing – landing or ejection), similarly to the Aero L-159 ALCA (see above). Other details of emergency procedures for this aircraft are currently classified and may not be published.

3. Common Features, Differences, Interesting Facts and Trends

Having examined complete original documentation for the crews of the different aircraft types, we can state the following facts:

The quality and form of flight manuals for the aircraft crews surprisingly does not depend so much on the type of the aircraftfor which they were intended, but they rather relate to the historical period in which they were drawn up, as they followed standards used in those historical periods. When the Czechoslovak and Czech Air Force used Soviet-made aircraft, the manuals were conceptually based on USSR standards; namely, from 1970s to 1990s, primarily GOST standards (in Russian "ГОСТ" for "ГОсударственный СТандарт" – "State Standard"). Since 1990s, the Czechoslovak and Czech Air Force have followed US Military Performance Specification (MIL-PRF) used by the United States Air Force (USAF).

The emergency procedures or flight manuals in general can be viewed in terms of graphic design, stylistic means, technical content and factual content. Each of these aspects has had its evolution.

As for the graphic design, the developmental trend has moved from annotated drawings and photographs to a bare text. It can be evidenced by original manuals for Soviet aircraft in Russian, such as [10] for example, that contain many graphical elements, especially drawings, photographs and graphs. With a little exaggeration, they resemble a comic book that demonstrates clearly and comprehensibly actual operations of the crew during flight. In the 1950s, the trends still strongly reflected the World War II when the manuals were, with almost no exception, largely illustrated and sometimes even colorful picture books. The hastily edited post-war Czechoslovak translations reduced the graphical elements. This trend has continued up to the present.

As for the stylistic means, the developmental trend has moved from full sentences to rather short comments in bullets (from 1950s to approximately 1980s) and then from those short comments in bullets to brief phrases and abbreviations (since 1980). The early flight manuals could be read as a largely comprehensible factual story even by a lay person. Contemporary manuals full of simple commands and foreign language abbreviations are no more intelligible for most people except professionals.

As for the factual content of the manuals, the developmental trend has moved from basic to complex extended commentaries (from 1950s to approximately 1980s) and then from complex extended commentaries to simplified commentaries (since 1980s). In the beginning of the 1950s when the first Mikoyan-Gurevich MiG-15s began to operate in the Czechoslovak Army Air Force, there was little experience with flying jet aircraft as well as with jet aircraft fires. The instructions were therefore very brief and did not even remotely cover the variety of situations that could occur during operation. Over time, in the light of reported air disasters, accidents and damages, the experiences continued to grow and the instructions were becoming more complex, i.e., they began to cover more types of emergencies and their solutions. Complex commentaries peaked at the turn of the 1980s. Since then, the instructions in manuals have been formulated ever more briefly and the move toward universality of the

procedures, when one solution covers more variants previously addressed by different procedures, is apparent. This relates also to technological advances with regard to safety elements and safety systems in aircraft. The increase in reliability or the possibility to use ejection seats may serve as an example.

As for the technical content, the developmental trends progressed particularly in fire alarm signaling, identification of fire location (in twin-engined aircraft), fire warning and fire suppression procedures and also in concepts of design and utilization of fire-protection elements.

Fire alarm signaling evolved from "none" through "optical" into combined "optical and acoustical". The early Avia S-92s (or CS-92s) and Yakovlev Yak-23s had no fire alarm signalization yet. Fire could only be detected by looking at the burning engine unit (only in the Avia S-92 or CS-92), by reflections of the flame on the canopy (again, only in the Avia S-92 or CS-92), by a smoke trail behind the aircraft visible in turns or by changing values on the flight instruments in the cockpit. The Mikoyan-Gurevich MiG-15 came with optical signalization represented by a red warning light in the left panel in the cockpit situated in the pilot's visual field. It was not until the Mikoyan-Gurevich MiG-23 that the optical signalization was accompanied by an acoustic one informing the pilot of the fire in his headset. This acoustical element is later present in the Mikoyan-Gurevich MiG-29, the Aero L-159 ALCA and the Saab JAS-39 Gripen, although the voice information is only used in the first two mentioned aircraft types. The Saab JAS-39 Gripen uses only specific non-verbal acoustic warning signal.

The identification of fire location became an issue with the advent of twin-engined fighters starting with the Mikoyan-Gurevich MiG-19, where the pilot during flight could not often identify which engine was burning. Both engine units would be sometimes shut off unnecessarily and the pilot would eject, although a safe landing with only one working engine was possible. The following twin-engined Sukhoi Su-25 and Mikoyan-Gurevich MiG-29 were yet equipped with such identification. The Ilyushin Il-28 jet bomber was an exception, as it was equipped with elements for fire location identification already in 1955 when it began to operate in the Czechoslovak People's Army Air Force.

The fire warning and fire suppression procedures evolved from three-staged (fire warning – fire extinguishing – landing or ejection) into four-staged (fire warning – verification – fire extinguishing – landing or ejection) beginning with the advent of the the Mikoyan-Gurevich MiG-21. The interesting fact is that in the Saab JAS-39 Gripen it is advised even after successful fire extinguishing that the crew eject if the engine has been shut off. For safety reasons, an attempt to perform an emergency landing with the engine off is advised against. There is maximum effort to eliminate all conditions for the occurrence of a disaster (loss of human lives).

The concepts of design and utilization of fire-protection elements have changed in the Czech Air Force with the advent of the Saab JAS-39 Gripen. The engine compartment has been designed to minimize the number of flammable components and zones that could contain flammable operating fluids. The entire engine compartment is separated from other structures by fire-resistant materials that make it possible to continue the flight with a burning engine for a certain time without endangering the crew or damaging any of the critical control systems. This is a step toward fire safety concepts that have been applied in civil aviation for many years.

4. Conclusion

The review shows that the concept of manuals for pilots of military jet fighters in Czechoslovakia and the Czech Republic, equipped with fire protection systems, has undergone a distinct evolution over the past sixty-five years. The level of knowledge and experience with jet flying has considerably increased, which is reflected in a more complex preparation of pilots for in-flight emergencies, as well as in enhancements in safety features in aircraft.

One should not forget, though, that besides theoretical preparation, it is the flight experience that is a precondition for a quality pilot training. Formerly, what the pilots might have missed in theoretical preparation, they caught up with extensive flight practice. Over the years, however, the ratio between the extent of theoretical training and flight practice has been dangerously changing in favor of theoretical training and due to political changes and the high cost of aircraft operation this trend continues. Any pilot would certainly affirm that no flight manual, no matter how well drafted, can compensate fot practical flight training. Training without theoretical preparation would not be possible either and today's quality of educational aviation documents proves that the work, dedication and commitment of previous generations of the flight and non-flight staff was of a great importance, for which they deserve our honest and sincere appreciation.

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