



1
00:00:31,029 --> 00:00:29,109
as part of a continuing program on

2
00:00:32,870 --> 00:00:31,039
aviation safety the lewis flank

3
00:00:34,709 --> 00:00:32,880
propulsion laboratory of the national

4
00:00:36,870 --> 00:00:34,719
advisory committee for aeronautics has

5
00:00:39,110 --> 00:00:36,880
been engaged in research on the start of

6
00:00:41,430 --> 00:00:39,120
fires that sometimes follow airplane

7
00:00:43,670 --> 00:00:41,440
crashes the work was undertaken at the

8
00:00:46,069 --> 00:00:43,680
recommendation of the naca committee on

9
00:00:48,790 --> 00:00:46,079
operating problems and the subcommittee

10
00:00:50,630 --> 00:00:48,800
on aircraft fire prevention these groups

11
00:00:53,350 --> 00:00:50,640
are made up of leading representatives

12
00:00:55,270 --> 00:00:53,360
of civil and military aviation it was

13
00:00:57,110 --> 00:00:55,280

the purpose of this research to provide

14

00:00:59,430 --> 00:00:57,120

a better understanding of the important

15

00:01:02,709 --> 00:00:59,440

factors involved in the start and spread

16

00:01:04,710 --> 00:01:02,719

of crash fires as a necessary first step

17

00:01:06,630 --> 00:01:04,720

leading to significant reduction in the

18

00:01:08,789 --> 00:01:06,640

crash fire hazard

19

00:01:11,109 --> 00:01:08,799

the work reported in this film covers

20

00:01:13,590 --> 00:01:11,119

only the research completed on airplanes

21

00:01:15,990 --> 00:01:13,600

powered with reciprocating engines

22

00:01:18,710 --> 00:01:16,000

a thorough review of civil and military

23

00:01:21,109 --> 00:01:18,720

crash fire records emphasize the need

24

00:01:23,109 --> 00:01:21,119

for well-defined information on how

25

00:01:25,270 --> 00:01:23,119

crash fires start

26
00:01:27,830 --> 00:01:25,280
this review showed this information can

27
00:01:28,870 --> 00:01:27,840
only be provided by full-scale crash

28
00:01:33,749 --> 00:01:28,880
study

29
00:01:36,069 --> 00:01:33,759
an naca research memorandum entitled

30
00:01:40,069 --> 00:01:36,079
analysis of multi-engine transport

31
00:01:42,390 --> 00:01:40,079
airplane fire records

32
00:01:44,390 --> 00:01:42,400
the need for a full-scale crash fire

33
00:01:46,310 --> 00:01:44,400
program established the united states

34
00:01:48,630 --> 00:01:46,320
air force provided a group of service

35
00:01:50,870 --> 00:01:48,640
weary aircraft marked for decommission

36
00:01:53,030 --> 00:01:50,880
with which to conduct the research a

37
00:01:55,030 --> 00:01:53,040
landing or takeoff accident was chosen

38
00:01:57,270 --> 00:01:55,040

for study because the chance for

39

00:01:59,350 --> 00:01:57,280

passenger survival of crash impact is

40

00:02:02,069 --> 00:01:59,360

highest in this type of crash which

41

00:02:03,990 --> 00:02:02,079

occurs at reduced airplane speed the

42

00:02:05,990 --> 00:02:04,000

airplanes were carefully instrumented to

43

00:02:06,950 --> 00:02:06,000

collect detailed information during the

44

00:02:09,749 --> 00:02:06,960

crash

45

00:02:12,229 --> 00:02:09,759

72 vapor detectors located in the engine

46

00:02:14,949 --> 00:02:12,239

the cell wings and fuselage registered

47

00:02:17,830 --> 00:02:14,959

the presence of combustible vapors over

48

00:02:20,070 --> 00:02:17,840

100 flame detectors similarly located

49

00:02:22,710 --> 00:02:20,080

recorded the origin and spread of fire

50

00:02:24,710 --> 00:02:22,720

throughout the aircraft structure

51
00:02:26,790 --> 00:02:24,720
all the main electrical circuits were

52
00:02:28,869 --> 00:02:26,800
monitored at the locations shown on this

53
00:02:29,990 --> 00:02:28,879
chart to indicate the presence of short

54
00:02:31,830 --> 00:02:30,000
circuits

55
00:02:34,070 --> 00:02:31,840
instrumentation was also provided to

56
00:02:37,830 --> 00:02:34,080
indicate the time at which fuel lines

57
00:02:42,229 --> 00:02:40,229
such detailed information is registered

58
00:02:44,710 --> 00:02:42,239
on this instrument panel inside a

59
00:02:46,630 --> 00:02:44,720
fireproof box carried in the airplane

60
00:02:51,509 --> 00:02:46,640
the instrument panel is photographed by

61
00:02:56,070 --> 00:02:53,670
in a crash operation the airplane is

62
00:02:58,630 --> 00:02:56,080
accelerated from rest under full power

63
00:03:01,750 --> 00:02:58,640

and is guided into a crash barrier by a

64

00:03:03,910 --> 00:03:01,760

slipper in sliding contact with a rail

65

00:03:07,350 --> 00:03:03,920

this barrier is composed of an abutment

66

00:03:09,509 --> 00:03:07,360

in the path of each landing gear wheel

67

00:03:11,430 --> 00:03:09,519

the abutment strip the landing gear from

68

00:03:13,350 --> 00:03:11,440

the airplane

69

00:03:15,830 --> 00:03:13,360

if propellers strike the abutment at

70

00:03:18,390 --> 00:03:15,840

full engine power to produce extensive

71

00:03:20,390 --> 00:03:18,400

damage to the engine the cell

72

00:03:22,949 --> 00:03:20,400

the pair of poles on each side of the

73

00:03:25,110 --> 00:03:22,959

abutment cut into the wing fuel tanks

74

00:03:27,110 --> 00:03:25,120

causing spillage of the fuel at the

75

00:03:29,509 --> 00:03:27,120

moment of crash impact the airplane is

76
00:03:31,430 --> 00:03:29,519
moving at about 90 miles an hour the

77
00:03:33,270 --> 00:03:31,440
airplane carries a thousand gallons of

78
00:03:36,070 --> 00:03:33,280
fuel in the tanks outboard of the

79
00:03:45,589 --> 00:03:36,080
nacelles the fuel is sometimes dyed red

80
00:03:49,430 --> 00:03:47,430
a detailed description of the method of

81
00:03:52,149 --> 00:03:49,440
conducting these crashes was published

82
00:03:53,750 --> 00:03:52,159
in the naca research memorandum entitled

83
00:03:56,070 --> 00:03:53,760
facilities and methods used in

84
00:03:59,030 --> 00:03:56,080
full-scale airplane crash fire

85
00:04:03,429 --> 00:04:01,509
to understand how crash fires begin it

86
00:04:05,509 --> 00:04:03,439
is necessary to learn where and when

87
00:04:07,509 --> 00:04:05,519
ignition sources exist and how the

88
00:04:09,589 --> 00:04:07,519

combustibles move from the spillage

89

00:04:11,910 --> 00:04:09,599

zones to the ignition sources while

90

00:04:13,509 --> 00:04:11,920

these sources are still potent many

91

00:04:15,670 --> 00:04:13,519

ignition sources are carried on the

92

00:04:17,110 --> 00:04:15,680

airplane others are generated in the

93

00:04:19,030 --> 00:04:17,120

crash area

94

00:04:21,189 --> 00:04:19,040

a large number of ignition sources are

95

00:04:23,590 --> 00:04:21,199

located in the engine nacelle which

96

00:04:25,590 --> 00:04:23,600

contains the engine and hot metal parts

97

00:04:27,590 --> 00:04:25,600

of the exhaust system

98

00:04:30,469 --> 00:04:27,600

flames appear at the engine intake in

99

00:04:32,710 --> 00:04:30,479

the familiar backfire

100

00:04:36,390 --> 00:04:32,720

likewise flames appear at the exhaust

101

00:04:40,070 --> 00:04:38,070

the electrical system of the airplane

102

00:04:42,230 --> 00:04:40,080

represents the most widely distributed

103

00:04:44,790 --> 00:04:42,240

ignition source it extends from the

104

00:04:47,270 --> 00:04:44,800

nacelles into the wings to power fuel

105

00:04:49,270 --> 00:04:47,280

pumps and lights into the fuselage for

106

00:04:51,830 --> 00:04:49,280

lights navigational instruments and

107

00:04:53,749 --> 00:04:51,840

airplane controls

108

00:04:55,990 --> 00:04:53,759

of the combustibles carried in an

109

00:04:58,230 --> 00:04:56,000

airplane only those in liquid form are

110

00:05:02,790 --> 00:04:58,240

likely to contact ignition sources in a

111

00:05:09,749 --> 00:05:05,430

hydraulic fluid

112

00:05:12,150 --> 00:05:09,759

lubricating oil and alcohol

113

00:05:14,230 --> 00:05:12,160

the crash fire threatens human survival

114

00:05:16,230 --> 00:05:14,240

only when the fuel becomes involved in

115

00:05:18,710 --> 00:05:16,240

the fire because the other combustibles

116

00:05:20,870 --> 00:05:18,720

are present in small quantities however

117

00:05:23,670 --> 00:05:20,880

the other liquid combustibles may be the

118

00:05:25,270 --> 00:05:23,680

first to ignite and in turn set fire to

119

00:05:27,270 --> 00:05:25,280

the fuel

120

00:05:29,990 --> 00:05:27,280

in the conventional airplane most of the

121

00:05:32,469 --> 00:05:30,000

fuel is stored in wing tanks the tanks

122

00:05:34,790 --> 00:05:32,479

are interconnected by pipes so that fuel

123

00:05:36,550 --> 00:05:34,800

from any tank can serve all the engines

124

00:05:38,469 --> 00:05:36,560

through main lines which run to the

125

00:05:40,870 --> 00:05:38,479

engine carburetor

126

00:05:43,749 --> 00:05:40,880

in a crash fuel often is spilled in

127

00:05:45,749 --> 00:05:43,759

liquid form from broken fuel lines

128

00:05:47,350 --> 00:05:45,759

likewise liquid spillage occurs from

129

00:05:49,909 --> 00:05:47,360

damaged tanks

130

00:05:52,550 --> 00:05:49,919

pre-mixed fuel vapor and air spills from

131

00:05:55,189 --> 00:05:52,560

the damaged engine induction system and

132

00:05:57,430 --> 00:05:55,199

a combustible fuel mist sometimes forms

133

00:05:59,749 --> 00:05:57,440

around the airplane the airplanes were

134

00:06:02,950 --> 00:05:59,759

crashed in ways that resulted in all

135

00:06:05,110 --> 00:06:02,960

these forms of fuel spillage

136

00:06:06,870 --> 00:06:05,120

in studying how the fires are started it

137

00:06:09,590 --> 00:06:06,880

is necessary to consider the ignition

138

00:06:11,110 --> 00:06:09,600

sources along with the fuel spillage the

139

00:06:13,270 --> 00:06:11,120

following discussion will take up the

140

00:06:15,830 --> 00:06:13,280

various forms of fuel spillage and how

141

00:06:17,430 --> 00:06:15,840

the fuel moves to the ignition sources

142

00:06:19,270 --> 00:06:17,440

the characteristics of the ignition

143

00:06:23,990 --> 00:06:19,280

sources will be discussed at the same

144

00:06:28,150 --> 00:06:26,309

because the fuel in the mist form played

145

00:06:30,550 --> 00:06:28,160

such an important role in the crash

146

00:06:32,710 --> 00:06:30,560

fires experienced in this study fires

147

00:06:35,350 --> 00:06:32,720

involving fuel mist will be discussed

148

00:06:37,189 --> 00:06:35,360

first when the liquid fuel spills into

149

00:06:42,390 --> 00:06:37,199

the open air while the airplane is in

150

00:06:47,029 --> 00:06:44,710

in this scene shown at one-fifth normal

151
00:06:49,350 --> 00:06:47,039
speed watch how the fuel dyed red for

152
00:06:51,990 --> 00:06:49,360
visual clarity develops into mist during

153
00:06:54,230 --> 00:06:52,000
a crash as the fuel pours from the tanks

154
00:06:56,870 --> 00:06:54,240
breached by the poles at the barrier the

155
00:06:58,950 --> 00:06:56,880
fuel is atomized to mist a part of which

156
00:07:00,870 --> 00:06:58,960
remains suspended in the air

157
00:07:02,710 --> 00:07:00,880
the plume of the fuel mist streams

158
00:07:04,870 --> 00:07:02,720
directly rearward from the break in the

159
00:07:06,710 --> 00:07:04,880
tanks if the damage to the airplane in

160
00:07:09,270 --> 00:07:06,720
the crash results in only moderate

161
00:07:11,510 --> 00:07:09,280
deceleration and the airplane continues

162
00:07:12,950 --> 00:07:11,520
forward at high speed when the airplane

163
00:07:15,670 --> 00:07:12,960

moves at low speed with high

164

00:07:17,909 --> 00:07:15,680

deceleration the fuel surges forward out

165

00:07:20,150 --> 00:07:17,919

of the break in the tank this results in

166

00:07:22,309 --> 00:07:20,160

a broad fuel mist pattern in the forward

167

00:07:24,309 --> 00:07:22,319

portions of the airplane under such

168

00:07:26,230 --> 00:07:24,319

conditions contact between fuel and

169

00:07:28,550 --> 00:07:26,240

ignition sources at the nacelle is

170

00:07:30,150 --> 00:07:28,560

likely

171

00:07:32,070 --> 00:07:30,160

now watch in the next crash the

172

00:07:34,230 --> 00:07:32,080

transition of the fuel mist development

173

00:07:35,990 --> 00:07:34,240

from the high speed low deceleration

174

00:07:37,990 --> 00:07:36,000

pattern to the low speed high

175

00:07:39,830 --> 00:07:38,000

deceleration pattern

176

00:07:42,150 --> 00:07:39,840

here comes the airplane at about 90

177

00:07:44,710 --> 00:07:42,160

miles an hour the motion is reduced to

178

00:07:46,870 --> 00:07:44,720

one-fifth normal speed the impact of the

179

00:07:49,350 --> 00:07:46,880

barrier will produce momentary moderate

180

00:07:51,990 --> 00:07:49,360

airplane decelerations observe that the

181

00:07:53,909 --> 00:07:52,000

fuel died red streams directly back from

182

00:07:55,189 --> 00:07:53,919

the leading edge when the airplane

183

00:07:57,909 --> 00:07:55,199

strikes the ground with high

184

00:07:59,589 --> 00:07:57,919

deceleration the fuel mist develops well

185

00:08:02,869 --> 00:07:59,599

forward of the wing leading edge and

186

00:08:05,270 --> 00:08:02,879

spreads span wise as the airplane slows

187

00:08:07,270 --> 00:08:05,280

in view of these effects the fuel mist

188

00:08:09,350 --> 00:08:07,280

can be expected to contact an ignition

189

00:08:11,430 --> 00:08:09,360

source which lies span wise from the

190

00:08:12,869 --> 00:08:11,440

point of fuel spillage as the airplane

191

00:08:14,550 --> 00:08:12,879

slows down

192

00:08:16,550 --> 00:08:14,560

in the motion pictures of the crash

193

00:08:18,469 --> 00:08:16,560

illustrating this effect look for a

194

00:08:20,950 --> 00:08:18,479

continuing series of flames at the

195

00:08:23,189 --> 00:08:20,960

engine exhaust following crash impacted

196

00:08:24,790 --> 00:08:23,199

the barrier as the airplane skids along

197

00:08:27,350 --> 00:08:24,800

the ground the fuel spilling from the

198

00:08:30,070 --> 00:08:27,360

wing at this location moves span wise in

199

00:08:39,509 --> 00:08:30,080

mist form until it reaches an exhaust

200

00:08:43,750 --> 00:08:41,509

now let us observe this method of fuel

201
00:08:46,070 --> 00:08:43,760
movement to the engine tailpipe the

202
00:08:52,829 --> 00:08:46,080
action here is reduced to one-fifth

203
00:08:58,470 --> 00:08:56,150
speed notice the flames at the tailpipe

204
00:09:00,870 --> 00:08:58,480
contact of the fuel mist with an exhaust

205
00:09:10,710 --> 00:09:00,880
flame occurs just as the airplane comes

206
00:09:14,630 --> 00:09:12,470
ignition of the fuel mist occurred on

207
00:09:16,630 --> 00:09:14,640
the same airplane on the hot exhaust

208
00:09:18,550 --> 00:09:16,640
collector ring of the engine on your

209
00:09:20,630 --> 00:09:18,560
left at this location

210
00:09:22,870 --> 00:09:20,640
under impact at the barrier the engine

211
00:09:25,430 --> 00:09:22,880
the cell breaks down and exposes the

212
00:09:28,070 --> 00:09:25,440
exhaust collector ring as the airplane

213
00:09:37,829 --> 00:09:28,080

slows the fuel mist moves span wise and

214

00:09:42,150 --> 00:09:39,829

here comes the same airplane watch how

215

00:09:43,829 --> 00:09:42,160

the nacelle on your left tips downward

216

00:09:46,150 --> 00:09:43,839

as the propeller hits the barrier

217

00:09:47,990 --> 00:09:46,160

exposing the exhaust collector ring the

218

00:09:49,990 --> 00:09:48,000

flame first appears at the top of the

219

00:09:56,870 --> 00:09:50,000

nacelle where the fuel mist contacts the

220

00:10:01,590 --> 00:09:58,790

in the time between initial fuel

221

00:10:03,829 --> 00:10:01,600

spillage and ignition and explosive fuel

222

00:10:05,829 --> 00:10:03,839

air mixture accumulated in the wing

223

00:10:11,030 --> 00:10:05,839

explosion of the mixture produced this

224

00:10:15,509 --> 00:10:13,509

fuels of low volatility and mist form

225

00:10:17,430 --> 00:10:15,519

ignite readily in spite of the fact they

226
00:10:20,310 --> 00:10:17,440
are safe in liquid form in the presence

227
00:10:22,630 --> 00:10:20,320
of open flames a wick saturated with

228
00:10:25,030 --> 00:10:22,640
this fuel can be ignited by the steady

229
00:10:26,710 --> 00:10:25,040
application of a flame the lighted match

230
00:10:34,630 --> 00:10:26,720
held above the surface of this low

231
00:10:39,430 --> 00:10:36,790
observe in the next crash the ignition

232
00:10:41,030 --> 00:10:39,440
of the mist of low volatility fuel by a

233
00:10:43,430 --> 00:10:41,040
tailpipe flame

234
00:10:45,750 --> 00:10:43,440
note also the backfire flame at the

235
00:10:48,150 --> 00:10:45,760
engine inlet that follows the main fuel

236
00:10:50,150 --> 00:10:48,160
ignition

237
00:10:52,630 --> 00:10:50,160
the tanks of the oncoming plane are

238
00:10:54,870 --> 00:10:52,640

filled with low volatility fuel this

239

00:10:59,509 --> 00:10:54,880

action is reduced to one-fifth normal

240

00:11:03,910 --> 00:11:01,430

here is the ignition by the tailpipe

241

00:11:20,710 --> 00:11:06,230

now watch for the backfire at the engine

242

00:11:24,870 --> 00:11:22,630

this aerial view of the crash with the

243

00:11:26,630 --> 00:11:24,880

action slowed to one third normal speed

244

00:11:28,710 --> 00:11:26,640

shows the flames traveling through the

245

00:11:37,910 --> 00:11:28,720

fuel mist at a rate comparable to that

246

00:11:41,990 --> 00:11:39,829

the flames at the engine exhaust that

247

00:11:43,910 --> 00:11:42,000

were observed igniting these mists may

248

00:11:46,790 --> 00:11:43,920

occur in a crash as long as the engine

249

00:11:48,550 --> 00:11:46,800

is rotating and drawing fuel even impact

250

00:11:50,310 --> 00:11:48,560

of the propellers with an obstacle does

251

00:11:56,550 --> 00:11:50,320

not ensure that the engine will stop

252

00:12:01,190 --> 00:11:58,949

in this crash shown at normal speed the

253

00:12:03,990 --> 00:12:01,200

damaged engines continues to operate for

254

00:12:06,389 --> 00:12:04,000

several minutes after crash impact watch

255

00:12:09,350 --> 00:12:06,399

how the propellers now in slow rotation

256

00:12:11,670 --> 00:12:09,360

accelerate this alternation of slow and

257

00:12:19,750 --> 00:12:11,680

fast rotation continues through several

258

00:12:24,150 --> 00:12:21,910

another ignition source in the engine

259

00:12:26,230 --> 00:12:24,160

cell which may ignite the fuel mist is

260

00:12:28,230 --> 00:12:26,240

provided by lubricating oil burning

261

00:12:30,310 --> 00:12:28,240

within the nacelle

262

00:12:32,470 --> 00:12:30,320

the next crash you will see shows how

263

00:12:33,350 --> 00:12:32,480

the lubricating oil can set fire to the

264

00:12:35,590 --> 00:12:33,360

fuel

265

00:12:37,670 --> 00:12:35,600

on the low wing airplane used in this

266

00:12:40,389 --> 00:12:37,680

crash the nacelle strike the ground when

267

00:12:42,150 --> 00:12:40,399

the landing gear is sheared off the oil

268

00:12:44,150 --> 00:12:42,160

cooler located at the bottom of the

269

00:12:46,310 --> 00:12:44,160

nacelle is ripped open when the cell

270

00:12:48,470 --> 00:12:46,320

strikes the ground the released oil is

271

00:12:55,269 --> 00:12:48,480

ignited on contact with the hot engine

272

00:12:59,350 --> 00:12:57,190

now we shall see how this fire setting

273

00:13:01,829 --> 00:12:59,360

process acts in a crash of a low wing

274

00:13:04,069 --> 00:13:01,839

airplane having the nacelle arrangements

275

00:13:06,389 --> 00:13:04,079

shown previously the action is reduced

276

00:13:08,710 --> 00:13:06,399

to 1 12 normal speed

277

00:13:10,629 --> 00:13:08,720

after passing through the crash barrier

278

00:13:13,030 --> 00:13:10,639

the unsupported airplane strikes the

279

00:13:15,350 --> 00:13:13,040

ground the cells foremost causing the

280

00:13:17,430 --> 00:13:15,360

oil cooler in the nacelle to break back

281

00:13:18,790 --> 00:13:17,440

and release oil onto the hot exhaust

282

00:13:21,190 --> 00:13:18,800

collector ring

283

00:13:23,670 --> 00:13:21,200

now condensed oil vapor generated on the

284

00:13:24,790 --> 00:13:23,680

exhaust system can be seen issuing from

285

00:13:27,030 --> 00:13:24,800

the nacelle

286

00:13:28,629 --> 00:13:27,040

as the airplane slows the fuel spilling

287

00:13:30,310 --> 00:13:28,639

from the wing moves out ahead of the

288

00:13:32,470 --> 00:13:30,320

leading edge and spreads toward the

289

00:13:34,870 --> 00:13:32,480

nacelle

290

00:13:36,710 --> 00:13:34,880

two seconds after crash impact ignition

291

00:13:39,190 --> 00:13:36,720

of the oil is indicated by the fire

292

00:13:41,030 --> 00:13:39,200

detectors a marked increase in the rate

293

00:13:43,590 --> 00:13:41,040

of formation of oil vapors follows

294

00:13:45,509 --> 00:13:43,600

ignition of the oil

295

00:13:47,910 --> 00:13:45,519

three seconds after crash impact the

296

00:13:49,670 --> 00:13:47,920

entire engine exhaust collector ring is

297

00:13:52,150 --> 00:13:49,680

enveloped in fire

298

00:13:54,389 --> 00:13:52,160

as the airplane comes to a stop the fuel

299

00:13:57,189 --> 00:13:54,399

mist and oil vapors form a continuous

300

00:13:59,189 --> 00:13:57,199

combustible atmosphere in a cell oil

301
00:14:01,269 --> 00:13:59,199
fire spreading through the oil mist will

302
00:14:03,350 --> 00:14:01,279
now appear outside of the nacelle and

303
00:14:05,189 --> 00:14:03,360
move rapidly to the fuel

304
00:14:07,110 --> 00:14:05,199
watch how the fire moves to the breach

305
00:14:09,269 --> 00:14:07,120
in the wing and then to the rear of the

306
00:14:11,110 --> 00:14:09,279
airplane as it follows the fuel spilled

307
00:14:17,350 --> 00:14:11,120
in the slide path of the crashed

308
00:14:21,990 --> 00:14:19,350
finally it is necessary to consider the

309
00:14:24,470 --> 00:14:22,000
time during which the mist is a hazard

310
00:14:26,710 --> 00:14:24,480
this is a rear view at one third normal

311
00:14:28,629 --> 00:14:26,720
speed which places the fuel mist between

312
00:14:30,470 --> 00:14:28,639
the airplane and the camera the

313
00:14:32,870 --> 00:14:30,480

developing fuel mist obscures the

314

00:14:35,430 --> 00:14:32,880

airplane from view but it reappears

315

00:14:37,670 --> 00:14:35,440

shortly as the large mist droplets rain

316

00:14:39,829 --> 00:14:37,680

to the ground and the small droplets are

317

00:14:42,310 --> 00:14:39,839

swept from the area by the wind as they

318

00:14:44,069 --> 00:14:42,320

evaporate these mists seldom remain

319

00:14:45,910 --> 00:14:44,079

around the crashed airplane for more

320

00:14:47,990 --> 00:14:45,920

than 15 seconds

321

00:14:50,550 --> 00:14:48,000

analysis of the photographic data shows

322

00:14:53,030 --> 00:14:50,560

that this fuel missed hazard time varies

323

00:15:00,069 --> 00:14:53,040

inversely with the wind speed around the

324

00:15:04,389 --> 00:15:01,829

to sum up it has been shown that

325

00:15:06,710 --> 00:15:04,399

airborne fuel mist can move considerable

326

00:15:08,949 --> 00:15:06,720

distance forward and span wise from the

327

00:15:11,030 --> 00:15:08,959

fuel spillage point to reach remote

328

00:15:13,110 --> 00:15:11,040

ignition sources

329

00:15:14,710 --> 00:15:13,120

when the fuel is dispersed as missed it

330

00:15:17,030 --> 00:15:14,720

ignites readily even though its

331

00:15:19,269 --> 00:15:17,040

volatility is low

332

00:15:21,509 --> 00:15:19,279

contact between the mist and an ignition

333

00:15:23,670 --> 00:15:21,519

source far from the fuel spillage zones

334

00:15:25,430 --> 00:15:23,680

is most likely to occur as the airplane

335

00:15:27,350 --> 00:15:25,440

slows down

336

00:15:29,430 --> 00:15:27,360

because of the short duration time of

337

00:15:31,350 --> 00:15:29,440

the mist the ignition source must be

338

00:15:34,310 --> 00:15:31,360

present while the airplane is in motion

339

00:15:36,069 --> 00:15:34,320

or shortly after it stops if a fire is

340

00:15:37,990 --> 00:15:36,079

to occur

341

00:15:39,910 --> 00:15:38,000

now let us see how crash fires are

342

00:15:42,389 --> 00:15:39,920

started with fuel spillage in liquid

343

00:15:44,389 --> 00:15:42,399

form fuel in liquid form appears on the

344

00:15:46,389 --> 00:15:44,399

outside of the airplane pouring to the

345

00:15:47,829 --> 00:15:46,399

ground from the broken fuel tank and

346

00:15:49,350 --> 00:15:47,839

fuel lines

347

00:15:51,749 --> 00:15:49,360

the steam that is issuing from the

348

00:15:53,749 --> 00:15:51,759

nacelle will be discussed later liquid

349

00:15:55,829 --> 00:15:53,759

fuel also collects on the airplane

350

00:15:58,230 --> 00:15:55,839

surfaces by interception of the fuel

351
00:16:00,230 --> 00:15:58,240
mist droplets while the streams of

352
00:16:02,310 --> 00:16:00,240
liquid fuel pouring to the ground are

353
00:16:04,550 --> 00:16:02,320
formed as the airplane comes to a stop

354
00:16:06,389 --> 00:16:04,560
and mist formation subsides

355
00:16:08,629 --> 00:16:06,399
spreading of the liquid fuel within the

356
00:16:10,790 --> 00:16:08,639
airplane structure begins as soon as the

357
00:16:13,350 --> 00:16:10,800
tanks are damaged regardless of the

358
00:16:15,670 --> 00:16:13,360
state of motion of the airplane

359
00:16:17,590 --> 00:16:15,680
when liquid fuel is spilled inside the

360
00:16:20,310 --> 00:16:17,600
airplane structure such as the wing

361
00:16:22,790 --> 00:16:20,320
interior combustible concentrations of

362
00:16:25,189 --> 00:16:22,800
fuel vapor accumulate readily and spread

363
00:16:27,189 --> 00:16:25,199

within the structure as an example of

364

00:16:29,990 --> 00:16:27,199

the ignition of fuel spilled within the

365

00:16:31,749 --> 00:16:30,000

wing observe the wing fire set by

366

00:16:33,110 --> 00:16:31,759

damaged landing lights on the leading

367

00:16:35,430 --> 00:16:33,120

edge of the wing

368

00:16:37,670 --> 00:16:35,440

the poles that rip open the fuel tanks

369

00:16:39,509 --> 00:16:37,680

also smash the landing lights and drive

370

00:16:41,990 --> 00:16:39,519

them into the wing where the

371

00:16:44,310 --> 00:16:42,000

incandescent filaments set fire to the

372

00:16:45,990 --> 00:16:44,320

fuel almost at once

373

00:16:48,550 --> 00:16:46,000

the next motion picture sequence

374

00:16:50,629 --> 00:16:48,560

projected at one-fifth normal speed

375

00:16:53,030 --> 00:16:50,639

shows ignition by the damaged landing

376

00:16:55,430 --> 00:16:53,040

lights the pole at the barrier drives

377

00:16:57,430 --> 00:16:55,440

the landing light into the fuel tanks

378

00:16:59,269 --> 00:16:57,440

the resulting fire spreads rapidly

379

00:17:17,590 --> 00:16:59,279

through the fuel mist to produce this

380

00:17:22,870 --> 00:17:20,470

the mass of fuel mist rises as it burns

381

00:17:24,789 --> 00:17:22,880

out the fuel evaporating from liquid

382

00:17:26,870 --> 00:17:24,799

spillage on the ground and the wetted

383

00:17:40,470 --> 00:17:26,880

surfaces of the airplane continues the

384

00:17:44,390 --> 00:17:42,470

the fuel that spills in the wing can

385

00:17:46,789 --> 00:17:44,400

also move through channels within the

386

00:17:48,870 --> 00:17:46,799

wing to ignition sources contained in

387

00:17:50,870 --> 00:17:48,880

other parts of the airplane

388

00:17:53,510 --> 00:17:50,880

one path this fuel may take is through

389

00:17:55,750 --> 00:17:53,520

the duct in the wing leading edge this

390

00:17:57,830 --> 00:17:55,760

duct carries hot air to warm the wing

391

00:17:58,789 --> 00:17:57,840

and prevent the accumulation of ice in

392

00:18:00,789 --> 00:17:58,799

flight

393

00:18:02,710 --> 00:18:00,799

the duct leads to a heat exchanger at

394

00:18:04,630 --> 00:18:02,720

the engine exhaust tailpipe which

395

00:18:06,630 --> 00:18:04,640

provides the necessary heat

396

00:18:09,110 --> 00:18:06,640

when this duct is ripped open as the

397

00:18:11,270 --> 00:18:09,120

poles tear through the wing some of the

398

00:18:13,430 --> 00:18:11,280

fuel issuing from the torn tanks is

399

00:18:16,150 --> 00:18:13,440

diverted into the duct

400

00:18:17,590 --> 00:18:16,160

this fuel flows by gravity to the hot

401
00:18:20,070 --> 00:18:17,600
heat exchanger

402
00:18:22,150 --> 00:18:20,080
upon ignition the flame flashes back

403
00:18:26,070 --> 00:18:22,160
through the hot air duct to the fuel in

404
00:18:30,070 --> 00:18:27,990
here is a crash in which these events

405
00:18:32,070 --> 00:18:30,080
occurred because the wing slopes

406
00:18:33,590 --> 00:18:32,080
gradually toward the nacelle a fuel

407
00:18:36,390 --> 00:18:33,600
flowing through the hot air duct

408
00:18:38,230 --> 00:18:36,400
requires 14 seconds to reach the cell

409
00:18:40,950 --> 00:18:38,240
since the action on film is reduced to

410
00:18:43,510 --> 00:18:40,960
one-fifth normal speed about one minute

411
00:18:45,270 --> 00:18:43,520
will pass before this ignition appears

412
00:18:53,190 --> 00:18:45,280
the steam which is issuing from the

413
00:18:57,909 --> 00:18:55,430

the fire will show first at the engine

414

00:18:59,990 --> 00:18:57,919

tailpipe heat exchanger on your right

415

00:19:07,270 --> 00:19:00,000

note the spread of the fire back to the

416

00:19:11,029 --> 00:19:09,350

in addition to the flow of liquid fuel

417

00:19:13,430 --> 00:19:11,039

through the internal channels of the

418

00:19:15,990 --> 00:19:13,440

airplane fuel and rivulets and sheets

419

00:19:18,630 --> 00:19:16,000

flows by gravity along the underside of

420

00:19:21,029 --> 00:19:18,640

inclined airplane services this will be

421

00:19:23,270 --> 00:19:21,039

called wetting conduction fuel which

422

00:19:25,270 --> 00:19:23,280

spills inside the wing can seep through

423

00:19:27,750 --> 00:19:25,280

seams in the wing's skin and cling to

424

00:19:29,430 --> 00:19:27,760

the under surface of the wing this fuel

425

00:19:31,830 --> 00:19:29,440

may then flow to other parts of the

426

00:19:34,070 --> 00:19:31,840

airplane where ignition sources exist

427

00:19:36,789 --> 00:19:34,080

the resulting fire travels back along

428

00:19:38,630 --> 00:19:36,799

the fuel path to the fuel source the

429

00:19:40,470 --> 00:19:38,640

wetting conduction of the fuel along the

430

00:19:42,710 --> 00:19:40,480

under surface of the inclined wing is

431

00:19:44,870 --> 00:19:42,720

illustrated by a simple experiment in

432

00:19:47,430 --> 00:19:44,880

which fuel issuing from an opening in a

433

00:19:50,310 --> 00:19:47,440

tube at the raised end wets and moves

434

00:19:52,310 --> 00:19:50,320

along the under surface to the low end

435

00:19:54,150 --> 00:19:52,320

the normal wing arrangement of airplanes

436

00:19:56,870 --> 00:19:54,160

may place the wingtips higher than the

437

00:19:59,190 --> 00:19:56,880

wing at the engine the cells for these

438

00:20:00,950 --> 00:19:59,200

airplanes the wetting conduction flow is

439

00:20:05,430 --> 00:20:00,960

toward the nacelle where ignition

440

00:20:09,190 --> 00:20:07,430

sometimes in a crash the wing

441

00:20:11,270 --> 00:20:09,200

inclination is even higher which

442

00:20:13,750 --> 00:20:11,280

increases the fuel movement by wetting

443

00:20:15,909 --> 00:20:13,760

conduction distribution of fuel by

444

00:20:18,310 --> 00:20:15,919

wetting conduction is shown on the

445

00:20:21,270 --> 00:20:18,320

underside of this wing of a crashed

446

00:20:23,430 --> 00:20:21,280

airplane which did not burn the fuel dye

447

00:20:25,909 --> 00:20:23,440

indicates the path of the fuel the

448

00:20:27,990 --> 00:20:25,919

continuous fuel wetted path extends from

449

00:20:32,710 --> 00:20:28,000

the break in the wing to the nacelle and

450

00:20:37,590 --> 00:20:34,870

here is how the wetting conduction flow

451
00:20:39,590 --> 00:20:37,600
looks immediately after a crash the fuel

452
00:20:42,310 --> 00:20:39,600
on the underside of the wing clings and

453
00:20:44,230 --> 00:20:42,320
flows by gravity along the wing span

454
00:20:45,830 --> 00:20:44,240
some of the fuel dripping off along the

455
00:20:48,230 --> 00:20:45,840
way

456
00:20:50,230 --> 00:20:48,240
fuel sometimes runs into the wheel well

457
00:20:53,110 --> 00:20:50,240
from broken tanks through channels in

458
00:20:54,870 --> 00:20:53,120
the wing structure

459
00:20:57,029 --> 00:20:54,880
here you see how it dripped and ran

460
00:20:59,110 --> 00:20:57,039
along various parts of the landing gear

461
00:21:08,230 --> 00:20:59,120
actuating system and along the strut

462
00:21:12,310 --> 00:21:10,549
any marked change in the surface along

463
00:21:14,390 --> 00:21:12,320

which wetting conduction of fuel is

464

00:21:16,710 --> 00:21:14,400

taking place may interrupt this fuel

465

00:21:18,710 --> 00:21:16,720

flow here we see how a sharp edged

466

00:21:20,789 --> 00:21:18,720

projection intercepts the wetting

467

00:21:26,070 --> 00:21:20,799

conduction fuel flow and prevents

468

00:21:30,070 --> 00:21:28,149

a slot in the rod provides the same

469

00:21:31,510 --> 00:21:30,080

interception of the wetting conduction

470

00:21:33,430 --> 00:21:31,520

flow

471

00:21:35,510 --> 00:21:33,440

in cases where wetting conduction or

472

00:21:37,909 --> 00:21:35,520

fuel flow through structural channels

473

00:21:40,549 --> 00:21:37,919

results in prolonged contact between an

474

00:21:43,029 --> 00:21:40,559

igniter and the fuel in liquid form the

475

00:21:47,669 --> 00:21:43,039

use of fuels of low volatility would not

476
00:21:51,830 --> 00:21:49,990
where vaporization of the fuel across an

477
00:21:54,630 --> 00:21:51,840
air gap is required for the fuel to

478
00:21:57,270 --> 00:21:54,640
reach an igniter low volatility fuel

479
00:21:59,510 --> 00:21:57,280
provides a safety advantage consider

480
00:22:01,750 --> 00:21:59,520
next fuel spilling in the open air that

481
00:22:03,510 --> 00:22:01,760
wets the ground along the slide path of

482
00:22:05,990 --> 00:22:03,520
the airplane and around the crashed

483
00:22:08,630 --> 00:22:06,000
airplane at rest the pools of liquid

484
00:22:10,710 --> 00:22:08,640
fuel close to the nacelles are not large

485
00:22:13,270 --> 00:22:10,720
since most of the spilled fuel flows

486
00:22:15,190 --> 00:22:13,280
away from the spillage point ignitable

487
00:22:17,029 --> 00:22:15,200
fuel vapor from ground spillage is

488
00:22:19,350 --> 00:22:17,039

carried in a thin layer close to the

489

00:22:21,270 --> 00:22:19,360

ground the ignition hazard distance

490

00:22:24,070 --> 00:22:21,280

which extends only a few feet from the

491

00:22:26,950 --> 00:22:24,080

spillage decreases with increasing wind

492

00:22:28,870 --> 00:22:26,960

velocity this short hazard distance is

493

00:22:31,590 --> 00:22:28,880

illustrated by the ignition of gasoline

494

00:22:33,990 --> 00:22:31,600

vapors from pans by a lighted taper

495

00:22:36,070 --> 00:22:34,000

approaching from the downwind end

496

00:22:37,990 --> 00:22:36,080

when ignition occurs the lighted taper

497

00:22:40,470 --> 00:22:38,000

lies within two inches of the surface of

498

00:22:43,029 --> 00:22:40,480

the gasoline contained in the pans the

499

00:22:45,190 --> 00:22:43,039

wind speed is 10 miles an hour movement

500

00:22:47,669 --> 00:22:45,200

of combustible concentrations of fuel

501
00:22:50,230 --> 00:22:47,679
vapors from fuels filled in the open air

502
00:22:56,070 --> 00:22:50,240
to ignition sources above the ground is

503
00:22:59,990 --> 00:22:58,070
however when the fuel is spilled into

504
00:23:02,710 --> 00:23:00,000
wind protected areas provided by the

505
00:23:05,190 --> 00:23:02,720
crashed airplane heavy ground vegetation

506
00:23:07,590 --> 00:23:05,200
or ground channels the combustible

507
00:23:09,909 --> 00:23:07,600
concentration of fuel vapors may travel

508
00:23:11,909 --> 00:23:09,919
a considerable distance the ignition

509
00:23:14,549 --> 00:23:11,919
source must appear close to the ground

510
00:23:16,710 --> 00:23:14,559
in order to contact these fuel vapors

511
00:23:19,830 --> 00:23:16,720
such ignition sources may be droplets of

512
00:23:22,149 --> 00:23:19,840
burning oil hydraulic fluid or pieces of

513
00:23:23,750 --> 00:23:22,159

hot metal broken from the engine exhaust

514

00:23:25,590 --> 00:23:23,760

disposal system

515

00:23:27,909 --> 00:23:25,600

friction sparks generated by the

516

00:23:31,029 --> 00:23:27,919

scraping of airplane metals on concrete

517

00:23:32,870 --> 00:23:31,039

runways or stony ground provide one type

518

00:23:35,110 --> 00:23:32,880

of ignition source which appears close

519

00:23:37,510 --> 00:23:35,120

to the ground these sparks may ignite

520

00:23:39,510 --> 00:23:37,520

fuel on the ground in order to study

521

00:23:41,350 --> 00:23:39,520

this type of ignition a concrete strip

522

00:23:43,750 --> 00:23:41,360

was built along the slide path of the

523

00:23:45,909 --> 00:23:43,760

crashed airplane

524

00:23:48,070 --> 00:23:45,919

selected samples of airplane metals were

525

00:23:50,310 --> 00:23:48,080

fastened to protruding ends of pneumatic

526

00:23:53,029 --> 00:23:50,320

wheel struts salvaged from airplanes

527

00:23:55,510 --> 00:23:53,039

crashed in this study upon crash these

528

00:23:57,510 --> 00:23:55,520

metal samples bear on the concrete strip

529

00:23:59,830 --> 00:23:57,520

with a contact force great enough to

530

00:24:02,070 --> 00:23:59,840

produce sparks of sufficient size and

531

00:24:04,789 --> 00:24:02,080

temperature to ignite aviation grade

532

00:24:07,190 --> 00:24:04,799

gasoline sparks from this portion of a

533

00:24:10,230 --> 00:24:07,200

steel propeller blade and this steel

534

00:24:12,149 --> 00:24:10,240

wheel strut produced fires

535

00:24:14,070 --> 00:24:12,159

a braided particles of this portion of

536

00:24:16,710 --> 00:24:14,080

an aluminum propeller blade did not

537

00:24:18,710 --> 00:24:16,720

produce ignition in order to ensure an

538

00:24:21,350 --> 00:24:18,720

ignitable mixture close to the ground

539

00:24:23,350 --> 00:24:21,360

near the sparks secondary fuel spillage

540

00:24:25,830 --> 00:24:23,360

was provided by the spray bar at the

541

00:24:30,549 --> 00:24:25,840

nose of the fuselage and these spray

542

00:24:34,470 --> 00:24:32,390

ignition will appear at this point on

543

00:24:37,669 --> 00:24:34,480

the fuselage where a portion of a steel

544

00:24:39,590 --> 00:24:37,679

propeller blade is located

545

00:24:41,830 --> 00:24:39,600

here we see the airplane sliding along

546

00:24:44,149 --> 00:24:41,840

the concrete strip after undergoing the

547

00:24:46,230 --> 00:24:44,159

usual crash damage at the barrier the

548

00:24:47,110 --> 00:24:46,240

action is slowed to one-fifth normal

549

00:24:48,630 --> 00:24:47,120

speed

550

00:24:50,470 --> 00:24:48,640

the ignition will appear at the bottom

551
00:24:52,789 --> 00:24:50,480
of the fuselage this is the first

552
00:24:54,950 --> 00:24:52,799
ignition and here is the second friction

553
00:24:57,430 --> 00:24:54,960
sparks obtained from steel and normal

554
00:24:59,350 --> 00:24:57,440
steel grinding operations seldom have

555
00:25:01,510 --> 00:24:59,360
enough size and temperature to ignite

556
00:25:03,590 --> 00:25:01,520
gasoline but these studies show that

557
00:25:06,149 --> 00:25:03,600
friction sparks of sufficient energy for

558
00:25:08,070 --> 00:25:06,159
ignition of gasoline can occur under the

559
00:25:12,230 --> 00:25:08,080
conditions of high friction loads which

560
00:25:16,549 --> 00:25:14,549
to summarize these results show that the

561
00:25:18,310 --> 00:25:16,559
ignitable vapor zones arising from

562
00:25:22,630 --> 00:25:18,320
liquid spilling in the open air are

563
00:25:24,789 --> 00:25:22,640

small except in wind protected areas

564

00:25:26,630 --> 00:25:24,799

liquid fuel spilled in the wings moves

565

00:25:28,710 --> 00:25:26,640

as liquid and vapor through the

566

00:25:30,710 --> 00:25:28,720

structural channels

567

00:25:32,630 --> 00:25:30,720

widespread distribution of a fuel in

568

00:25:34,070 --> 00:25:32,640

liquid form can occur by wetting

569

00:25:35,990 --> 00:25:34,080

conduction

570

00:25:37,750 --> 00:25:36,000

in contrast with a fuel mist which

571

00:25:40,070 --> 00:25:37,760

persists for only a few seconds in the

572

00:25:41,590 --> 00:25:40,080

crash area the fuel and liquid form on

573

00:25:43,669 --> 00:25:41,600

the ground and the wetted surfaces of

574

00:25:46,070 --> 00:25:43,679

the airplane and in the channels of the

575

00:25:47,029 --> 00:25:46,080

airplane structure are present for long

576

00:25:48,870 --> 00:25:47,039

periods

577

00:25:50,870 --> 00:25:48,880

these are the forms of fuel spillage

578

00:25:57,269 --> 00:25:50,880

that are inflamed by ignition sources

579

00:26:01,510 --> 00:25:59,510

the ignition of fuel pre-mixed with air

580

00:26:03,909 --> 00:26:01,520

in combustible proportions is another

581

00:26:05,909 --> 00:26:03,919

way in which a crash fire may begin

582

00:26:08,230 --> 00:26:05,919

such fuel air mixtures appear in the

583

00:26:10,549 --> 00:26:08,240

engine air induction system comprising

584

00:26:12,789 --> 00:26:10,559

the supercharger and engine intake

585

00:26:14,870 --> 00:26:12,799

manifold a rupture of the engine

586

00:26:16,549 --> 00:26:14,880

induction system is followed at once by

587

00:26:18,710 --> 00:26:16,559

release of the fuel air mixture

588

00:26:20,070 --> 00:26:18,720

contained under pressure by the engine

589

00:26:22,149 --> 00:26:20,080

supercharger

590

00:26:24,149 --> 00:26:22,159

ignition may occur by contact of this

591

00:26:26,870 --> 00:26:24,159

released fuel air mixture with the hot

592

00:26:29,990 --> 00:26:26,880

elements of the exhaust disposal system

593

00:26:32,470 --> 00:26:30,000

or exposed exhaust pipes by arcs and

594

00:26:40,470 --> 00:26:32,480

sparks of the electrical system or by

595

00:26:44,549 --> 00:26:42,549

because of the high air flow rates

596

00:26:46,390 --> 00:26:44,559

through the engine the cell in the early

597

00:26:48,710 --> 00:26:46,400

phases of a crash when the airplane is

598

00:26:50,870 --> 00:26:48,720

moving at high speed ignition of this

599

00:26:53,190 --> 00:26:50,880

released fuel air mixture must occur

600

00:26:55,669 --> 00:26:53,200

shortly after engine induction system

601
00:26:57,909 --> 00:26:55,679
failure otherwise the fuel air mixture

602
00:27:00,710 --> 00:26:57,919
is quickly swept from the nacelle by the

603
00:27:02,549 --> 00:27:00,720
airflow although the fire produced by

604
00:27:04,870 --> 00:27:02,559
the ignition of the engine induction

605
00:27:06,470 --> 00:27:04,880
system fuel is not serious in itself

606
00:27:09,110 --> 00:27:06,480
because of the small amount of fuel

607
00:27:11,350 --> 00:27:09,120
involved this fire can extend to other

608
00:27:14,230 --> 00:27:11,360
fuel being spilled and so set off the

609
00:27:16,070 --> 00:27:14,240
major fire in the next crash to be shown

610
00:27:18,310 --> 00:27:16,080
the engine on your right breaks out of

611
00:27:20,310 --> 00:27:18,320
its nacelle at the moment of impact the

612
00:27:22,549 --> 00:27:20,320
engine fractures along the line passing

613
00:27:24,710 --> 00:27:22,559

through the case of the supercharger the

614

00:27:27,029 --> 00:27:24,720

released fuel air mixture is ignited at

615

00:27:31,029 --> 00:27:27,039

once by exhaust flame issuing from the

616

00:27:33,029 --> 00:27:31,039

adjacent broken engine exhaust

617

00:27:35,350 --> 00:27:33,039

here the airplane approaches the crash

618

00:27:37,750 --> 00:27:35,360

barrier the action is shown at 1 12

619

00:27:40,310 --> 00:27:37,760

normal speed watch the engine in full

620

00:27:42,870 --> 00:27:40,320

view snap from its mounts ignition of

621

00:27:44,710 --> 00:27:42,880

the fuel air mixture occurs at once the

622

00:27:47,269 --> 00:27:44,720

fuel being spilled adjacent to the

623

00:27:52,630 --> 00:27:47,279

nacelle is then ignited from this flash

624

00:27:56,789 --> 00:27:55,029

another crash fire involving ignition of

625

00:27:58,789 --> 00:27:56,799

the engine induction system fuel

626

00:28:01,110 --> 00:27:58,799

occurred in the following sequence

627

00:28:03,350 --> 00:28:01,120

damage to the engine induction system on

628

00:28:05,269 --> 00:28:03,360

crash impact resulted in a fire at the

629

00:28:08,310 --> 00:28:05,279

nacelle in a manner similar to that

630

00:28:10,549 --> 00:28:08,320

shown in a previous crash

631

00:28:12,870 --> 00:28:10,559

fuel spilling from the broken main fuel

632

00:28:14,789 --> 00:28:12,880

line at the nacelle firewall was ignited

633

00:28:17,190 --> 00:28:14,799

by the flash fire of the engine

634

00:28:19,430 --> 00:28:17,200

induction system fuel the resulting

635

00:28:22,389 --> 00:28:19,440

flames streamed rearward over the

636

00:28:24,070 --> 00:28:22,399

nacelle and wing

637

00:28:25,830 --> 00:28:24,080

afterwards the fuel spilling from the

638

00:28:28,310 --> 00:28:25,840

wings through the ruptures cut by the

639

00:28:30,470 --> 00:28:28,320

poles at the crash barrier fanned out

640

00:28:32,310 --> 00:28:30,480

into the wake of the wing contact

641

00:28:34,389 --> 00:28:32,320

between the flames and the fuel took

642

00:28:40,789 --> 00:28:34,399

place to the rear of the trailing edge

643

00:28:44,630 --> 00:28:43,110

the flames moved forward to the wing

644

00:28:46,870 --> 00:28:44,640

through the trailing fuel as the

645

00:28:51,510 --> 00:28:46,880

airplane speed fell below the flame

646

00:28:55,990 --> 00:28:53,590

now watch this fire setting mechanism in

647

00:28:58,310 --> 00:28:56,000

the next movie sequence at normal speed

648

00:29:03,590 --> 00:28:58,320

watch the nacelle and note the forward

649

00:29:07,190 --> 00:29:05,510

the research up to this point resulted

650

00:29:09,350 --> 00:29:07,200

in an understanding of the ignition

651
00:29:12,070 --> 00:29:09,360
sources involved in a series of crash

652
00:29:14,470 --> 00:29:12,080
fires and also how the fuel in the mist

653
00:29:16,870 --> 00:29:14,480
liquid and vapor forms moved from the

654
00:29:19,110 --> 00:29:16,880
spillage point to the ignition sources

655
00:29:21,350 --> 00:29:19,120
however these ignition sources revealed

656
00:29:23,830 --> 00:29:21,360
so far usually produced fires within a

657
00:29:25,750 --> 00:29:23,840
few seconds after crash impact

658
00:29:28,070 --> 00:29:25,760
because it was felt these early fires

659
00:29:30,710 --> 00:29:28,080
might mask other ways in which fire can

660
00:29:38,149 --> 00:29:30,720
occur the known ignition sources were

661
00:29:42,070 --> 00:29:40,549
the parts of the inerting system used in

662
00:29:44,630 --> 00:29:42,080
this investigation are shown

663
00:29:46,870 --> 00:29:44,640

diagrammatically on this chart

664

00:29:49,430 --> 00:29:46,880

here are the main parts of a typical

665

00:29:51,350 --> 00:29:49,440

engine nacelle to prevent the appearance

666

00:29:53,909 --> 00:29:51,360

of flames at the engine inlet and

667

00:29:56,630 --> 00:29:53,919

exhaust outlet fuel system shutoff

668

00:29:59,029 --> 00:29:56,640

valves are installed at the engine

669

00:30:01,029 --> 00:29:59,039

and the firewall to stop the fuel flow

670

00:30:03,029 --> 00:30:01,039

following crash impact

671

00:30:04,870 --> 00:30:03,039

one valve stops the fuel flow to the

672

00:30:07,830 --> 00:30:04,880

engine the other prevents the fuel

673

00:30:09,990 --> 00:30:07,840

spillage into the nacelle several pounds

674

00:30:12,470 --> 00:30:10,000

of suitable fire extinguishing agent

675

00:30:15,350 --> 00:30:12,480

discharged uniformly in the engine inlet

676
00:30:17,350 --> 00:30:15,360
air to inert the contents of the engine

677
00:30:22,070 --> 00:30:17,360
during the period of time required for

678
00:30:27,029 --> 00:30:24,310
electrical system switch shuts down the

679
00:30:28,710 --> 00:30:27,039
airplane battery and generator circuits

680
00:30:30,710 --> 00:30:28,720
the ignition system continues to

681
00:30:32,389 --> 00:30:30,720
function so that fuel passing into the

682
00:30:34,950 --> 00:30:32,399
engine will be burned in the normal

683
00:30:37,110 --> 00:30:34,960
manner in case the fuel shut off valves

684
00:30:40,070 --> 00:30:37,120
and the fire extinguishing agent system

685
00:30:42,389 --> 00:30:40,080
at the engine inlet are slow to function

686
00:30:45,110 --> 00:30:42,399
normal engine exhaust is less likely to

687
00:30:47,269 --> 00:30:45,120
start a fire than tail pipe flame which

688
00:30:49,909 --> 00:30:47,279

forms that when the fuel charge passes

689

00:30:52,070 --> 00:30:49,919

through the engine cylinder unburned and

690

00:30:53,190 --> 00:30:52,080

is later ignited in the hot exhaust

691

00:30:55,269 --> 00:30:53,200

system

692

00:30:57,510 --> 00:30:55,279

in order to prevent ignition on the hot

693

00:30:59,990 --> 00:30:57,520

metal of the exhaust system a water

694

00:31:01,750 --> 00:31:00,000

spray is used to cool all of the exposed

695

00:31:04,230 --> 00:31:01,760

metal which is hot enough to ignite the

696

00:31:06,389 --> 00:31:04,240

combustible in a few seconds needed to

697

00:31:08,789 --> 00:31:06,399

cool the metal to safe temperatures and

698

00:31:10,470 --> 00:31:08,799

inert atmosphere of steam generated by

699

00:31:13,190 --> 00:31:10,480

the water evaporating from the metal

700

00:31:15,669 --> 00:31:13,200

itself shrouds this potential ignition

701
00:31:17,590 --> 00:31:15,679
source to render it impotent the portion

702
00:31:19,909 --> 00:31:17,600
of the water spray system which services

703
00:31:22,230 --> 00:31:19,919
the exhaust collector ring is this

704
00:31:24,310 --> 00:31:22,240
three-quarter inch diameter tubing bent

705
00:31:26,710 --> 00:31:24,320
to conform approximately to the shape of

706
00:31:28,789 --> 00:31:26,720
the collector ring the exhaust system

707
00:31:30,630 --> 00:31:28,799
receives water over its entire surface

708
00:31:32,630 --> 00:31:30,640
from its spray nozzle

709
00:31:34,789 --> 00:31:32,640
the effectiveness of the water spray in

710
00:31:36,549 --> 00:31:34,799
preventing ignition on the hot exhaust

711
00:31:39,029 --> 00:31:36,559
is demonstrated by the rapidity with

712
00:31:40,710 --> 00:31:39,039
which a continuously fed oil fire

713
00:31:43,029 --> 00:31:40,720

burning from the exhaust system is

714

00:31:44,870 --> 00:31:43,039

extinguished by the water spray

715

00:31:47,190 --> 00:31:44,880

notice how the application of the water

716

00:31:59,190 --> 00:31:47,200

spray extinguishes the fire almost at

717

00:32:03,190 --> 00:32:01,110

this crash is typical of the results

718

00:32:05,110 --> 00:32:03,200

obtained with five aircraft equipped

719

00:32:06,950 --> 00:32:05,120

with the experimental inerting system

720

00:32:09,029 --> 00:32:06,960

just described which is arranged to be

721

00:32:11,430 --> 00:32:09,039

actuated as soon as possible after a

722

00:32:13,509 --> 00:32:11,440

crash impacted the barrier

723

00:32:15,350 --> 00:32:13,519

the only visible sign of the functioning

724

00:32:17,990 --> 00:32:15,360

of the inerting system is the steam

725

00:32:19,669 --> 00:32:18,000

evaporating from the hot exhaust system

726

00:32:22,149 --> 00:32:19,679

this is the steam which was visible in

727

00:32:24,149 --> 00:32:22,159

some of the preceding pictures the fuel

728

00:32:26,070 --> 00:32:24,159

here has been dyed red

729

00:32:28,070 --> 00:32:26,080

see the dust being raised by the

730

00:32:30,789 --> 00:32:28,080

airplane fuselage skidding along the

731

00:32:32,549 --> 00:32:30,799

ground this dust plays an important part

732

00:32:33,590 --> 00:32:32,559

in starting fires to be described

733

00:32:35,830 --> 00:32:33,600

shortly

734

00:32:37,830 --> 00:32:35,840

this experimental inerting system used

735

00:32:39,990 --> 00:32:37,840

in this crash was devised solely for

736

00:32:42,070 --> 00:32:40,000

studies of this kind and does not

737

00:32:44,070 --> 00:32:42,080

incorporate the considerations of weight

738

00:32:45,830 --> 00:32:44,080

and bulk which would be involved in

739

00:32:47,190 --> 00:32:45,840

inerting equipment for operating

740

00:32:49,190 --> 00:32:47,200

aircraft

741

00:32:51,029 --> 00:32:49,200

in this phase of the research in which

742

00:32:52,789 --> 00:32:51,039

aircraft carrying the experimental

743

00:32:56,070 --> 00:32:52,799

inerting system were subjected to

744

00:32:58,470 --> 00:32:56,080

moderate damage upon crash impact no new

745

00:33:00,870 --> 00:32:58,480

ignition sources were revealed

746

00:33:02,630 --> 00:33:00,880

after five crashes in which no fires

747

00:33:04,630 --> 00:33:02,640

were obtained and no new ignition

748

00:33:06,789 --> 00:33:04,640

sources were observed the crash

749

00:33:08,870 --> 00:33:06,799

circumstances were modified in an effort

750

00:33:12,070 --> 00:33:08,880

to learn other ways in which fires may

751
00:33:14,149 --> 00:33:12,080
occur in order to learn whether ignition

752
00:33:15,990 --> 00:33:14,159
sources may be created by the tearing

753
00:33:17,750 --> 00:33:16,000
and twisting of the airplane structure

754
00:33:19,590 --> 00:33:17,760
in a severe crash

755
00:33:21,350 --> 00:33:19,600
the forward portion of the fuselage

756
00:33:25,029 --> 00:33:21,360
structure was crushed along this

757
00:33:26,870 --> 00:33:25,039
inclined line in one crash as before the

758
00:33:28,870 --> 00:33:26,880
nacelles carried the experimental

759
00:33:30,950 --> 00:33:28,880
inerting system in the pictures which

760
00:33:32,870 --> 00:33:30,960
follow note the complete collapse of

761
00:33:34,870 --> 00:33:32,880
this fuselage force structure bringing

762
00:33:36,630 --> 00:33:34,880
the wings to ground level and the

763
00:33:42,870 --> 00:33:36,640

resulting wetting of this structure by

764

00:33:46,870 --> 00:33:44,710

while no fire occurred around the

765

00:33:49,110 --> 00:33:46,880

crushed structure ignition of the fuel

766

00:33:51,350 --> 00:33:49,120

did occur in the fuel wetted wake of the

767

00:33:53,590 --> 00:33:51,360

airplane the ignition source was an

768

00:33:55,990 --> 00:33:53,600

electric spark discharging to the ground

769

00:33:58,070 --> 00:33:56,000

from the landing gear strut which broke

770

00:33:59,750 --> 00:33:58,080

off in the crash and tumbled in the wake

771

00:34:01,830 --> 00:33:59,760

of the airplane

772

00:34:04,149 --> 00:34:01,840

here the airplane approaches the crash

773

00:34:06,389 --> 00:34:04,159

barrier upon impact with the ground the

774

00:34:09,109 --> 00:34:06,399

forward structure collapses the action

775

00:34:11,109 --> 00:34:09,119

here is slowed to one-fifth normal speed

776

00:34:12,950 --> 00:34:11,119

now watch the wheel strut tumbling in

777

00:34:15,190 --> 00:34:12,960

the wake of the airplane and observe the

778

00:34:17,349 --> 00:34:15,200

ignition which occurs when the metal end

779

00:34:19,190 --> 00:34:17,359

of the strut approaches the ground the

780

00:34:21,510 --> 00:34:19,200

fire spreads through the fuel in the

781

00:34:23,030 --> 00:34:21,520

airplane wake there is no evidence of

782

00:34:25,349 --> 00:34:23,040

other ignition resulting from the

783

00:34:28,629 --> 00:34:25,359

destruction of the fuselage structure or

784

00:34:30,149 --> 00:34:28,639

the inerted engine the cells the igniter

785

00:34:32,069 --> 00:34:30,159

in this instance proved to be an

786

00:34:34,389 --> 00:34:32,079

electric spark discharging from the

787

00:34:36,310 --> 00:34:34,399

landing gear strut to the ground the

788

00:34:38,550 --> 00:34:36,320

necessary electrical potential on the

789

00:34:40,470 --> 00:34:38,560

strut was generated in its passage

790

00:34:47,510 --> 00:34:40,480

through the dust and fuel mist in the

791

00:34:52,230 --> 00:34:49,669

ground studies were conducted by blowing

792

00:34:54,069 --> 00:34:52,240

dust and fuel over a landing gear strut

793

00:34:55,990 --> 00:34:54,079

and measuring the electrical potential

794

00:34:58,470 --> 00:34:56,000

built up on the surface of the landing

795

00:35:01,030 --> 00:34:58,480

gear here is the landing gear strut

796

00:35:03,109 --> 00:35:01,040

electrically insulated from its supports

797

00:35:05,190 --> 00:35:03,119

when dust is introduced into the air

798

00:35:06,870 --> 00:35:05,200

blowing over the strut at speeds equal

799

00:35:09,510 --> 00:35:06,880

to that of the strut moving through the

800

00:35:11,430 --> 00:35:09,520

air in the crash potentials in excess of

801
00:35:13,829 --> 00:35:11,440
twenty thousand volts are generated on

802
00:35:16,230 --> 00:35:13,839
the strut almost at once

803
00:35:18,710 --> 00:35:16,240
this voltage applied across a spark gap

804
00:35:20,790 --> 00:35:18,720
located in this small pan containing a

805
00:35:23,430 --> 00:35:20,800
pool of gasoline produces ignition of

806
00:35:27,030 --> 00:35:23,440
the gasoline

807
00:35:29,030 --> 00:35:27,040
here is the flaming gasoline

808
00:35:31,349 --> 00:35:29,040
in the last crash of this series the

809
00:35:33,270 --> 00:35:31,359
effect of an airplane ground loop on the

810
00:35:35,829 --> 00:35:33,280
distribution of the spill fuel was

811
00:35:38,550 --> 00:35:35,839
studied watch how the airplane ground

812
00:35:40,470 --> 00:35:38,560
loops as one landing gear is torn away

813
00:35:43,270 --> 00:35:40,480

the ground loop places the airplane and

814

00:35:45,190 --> 00:35:43,280

the fuel spray the fuselage wing and the

815

00:35:47,750 --> 00:35:45,200

cell on the right side of the airplane

816

00:35:50,069 --> 00:35:47,760

are wetted heavily with fuel because the

817

00:35:52,630 --> 00:35:50,079

inerting system carried on this airplane

818

00:35:55,990 --> 00:35:52,640

functioned properly and no new ignition

819

00:35:57,910 --> 00:35:56,000

sources appeared no fires occurred

820

00:36:00,310 --> 00:35:57,920

and now here's a summary of the crash

821

00:36:02,790 --> 00:36:00,320

fire research from two lewis flight

822

00:36:04,710 --> 00:36:02,800

propulsion laboratory scientists irving

823

00:36:07,109 --> 00:36:04,720

pinkel associate chief of the physics

824

00:36:11,109 --> 00:36:07,119

division and merit preston chief of the

825

00:36:13,430 --> 00:36:11,119

flight research branch mr pinkle

826

00:36:15,349 --> 00:36:13,440

the results of this work indicate that

827

00:36:17,589 --> 00:36:15,359

significant reduction in crash fire

828

00:36:18,630 --> 00:36:17,599

hazard can be realized by design

829

00:36:22,390 --> 00:36:18,640

measures

830

00:36:24,950 --> 00:36:22,400

that increase the span wise and forward

831

00:36:28,150 --> 00:36:24,960

distance and the elevation of the

832

00:36:30,069 --> 00:36:28,160

engines with respect to the fuel storage

833

00:36:32,470 --> 00:36:30,079

this trend in airplane component

834

00:36:35,349 --> 00:36:32,480

arrangement decreases the likelihood of

835

00:36:37,589 --> 00:36:35,359

contact between the fuel mist

836

00:36:38,829 --> 00:36:37,599

and the many ignition sources located at

837

00:36:42,630 --> 00:36:38,839

the engine in the

838

00:36:45,750 --> 00:36:42,640

cell fuel stored in wingtip tanks or in

839

00:36:47,990 --> 00:36:45,760

Pods suspended below the wing represent

840

00:36:50,230 --> 00:36:48,000

current design trends

841

00:36:51,670 --> 00:36:50,240

which decrease the likelihood of contact

842

00:36:54,790 --> 00:36:51,680

between the fuel

843

00:36:56,390 --> 00:36:54,800

and the ignition sources devices or

844

00:36:58,870 --> 00:36:56,400

design features

845

00:37:01,349 --> 00:36:58,880

which act to intercept spilled fuel

846

00:37:03,910 --> 00:37:01,359

flowing within the airplane structure

847

00:37:05,589 --> 00:37:03,920

are also valuable

848

00:37:07,589 --> 00:37:05,599

provisions for the drainage of this

849

00:37:10,069 --> 00:37:07,599

intercepted fuel

850

00:37:12,310 --> 00:37:10,079

into the open air at spillage points

851
00:37:14,150 --> 00:37:12,320
away from the engine the cells

852
00:37:16,150 --> 00:37:14,160
would enhance the effectiveness of these

853
00:37:18,470 --> 00:37:16,160
arrangements

854
00:37:20,230 --> 00:37:18,480
location of landing lights away from

855
00:37:22,310 --> 00:37:20,240
cordwise positions

856
00:37:24,310 --> 00:37:22,320
in front of the fuel storage is

857
00:37:26,390 --> 00:37:24,320
indicated as well

858
00:37:28,870 --> 00:37:26,400
because these studies show how readily

859
00:37:31,109 --> 00:37:28,880
combustibles spilled in the cell are

860
00:37:33,750 --> 00:37:31,119
ignited it is desirable that the

861
00:37:36,230 --> 00:37:33,760
components of the fuel lubricating and

862
00:37:38,550 --> 00:37:36,240
hydraulic systems should be located high

863
00:37:40,950 --> 00:37:38,560

in the cell where crash damage to these

864

00:37:43,349 --> 00:37:40,960

compounds is least likely

865

00:37:45,430 --> 00:37:43,359

tubing containing combustibles should be

866

00:37:47,670 --> 00:37:45,440

designed to accommodate the cell

867

00:37:49,510 --> 00:37:47,680

distortions accompanying propeller and

868

00:37:51,910 --> 00:37:49,520

the cell impact

869

00:37:54,150 --> 00:37:51,920

preliminary data suggests the value of

870

00:37:55,829 --> 00:37:54,160

employing special paints which reduce

871

00:37:58,150 --> 00:37:55,839

the tendency toward the formation of

872

00:38:00,069 --> 00:37:58,160

electrostatic sparks on parts of the

873

00:38:01,030 --> 00:38:00,079

airplane likely to be detached in the

874

00:38:03,670 --> 00:38:01,040

crash

875

00:38:06,150 --> 00:38:03,680

and trail in the dust and fuel in the

876

00:38:08,150 --> 00:38:06,160

wake of the crashed airplane

877

00:38:09,109 --> 00:38:08,160

in an approach to an indicated price

878

00:38:11,030 --> 00:38:09,119

landing

879

00:38:12,950 --> 00:38:11,040

the pilot should de-energize all of the

880

00:38:14,150 --> 00:38:12,960

electrical system not required for the

881

00:38:15,910 --> 00:38:14,160

landing

882

00:38:17,990 --> 00:38:15,920

engine operation that provides the

883

00:38:20,150 --> 00:38:18,000

coolest exhaust disposal system should

884

00:38:22,230 --> 00:38:20,160

be practiced consistent with other

885

00:38:24,310 --> 00:38:22,240

safety considerations

886

00:38:26,550 --> 00:38:24,320

just before touchdown the fuel flow to

887

00:38:29,349 --> 00:38:26,560

the engine should be cut off to allow

888

00:38:31,190 --> 00:38:29,359

the engine to be purged with clean air

889

00:38:33,109 --> 00:38:31,200

in view of the effectiveness of the

890

00:38:35,349 --> 00:38:33,119

experimental ignition source alerting

891

00:38:37,510 --> 00:38:35,359

system in preventing crash fires

892

00:38:39,510 --> 00:38:37,520

experienced in this research

893

00:38:42,630 --> 00:38:39,520

further study of this system for special

894

00:38:44,790 --> 00:38:42,640

airplane application is desirable

895

00:38:47,589 --> 00:38:44,800

material covered in this motion picture

896

00:38:50,630 --> 00:38:47,599

has been published in an naca research