HELICOPTER SAFETY:
THE SAFE USE OF HELICOPTERS IN FIRE SUPPRESSION
AND PRESCRIBED BURNING OPERATIONS

by

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to the required standard

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ABSTRACT

In recent years, forestry programmes in British Columbia have increasingly used helicopters to expedite operations, particularly in the areas of fire suppression and prescribed burning. Between 1970 and 1977 the population of Canadian helicopters doubled, reflecting the increased usage resulting from new, more efficient designs. The number of accidents per year decreased in the 8 years, but the percentage of fatal accidents increased. In British Columbia, the accident rate per 10,000 hours in the years 1975 and 1976, was 3.6, the third highest in Canada.

After an extensive period of field work in this province, by the author, it is clear that the people working in and around helicopters do not generally receive enough training in the safety precautions necessary. This lack of training was evident at both the worker level and the supervisory level. In fire suppression operations, the inadequate training is aggravated by haste, which greatly increases the chances of unnecessary accidents.

This report identifies areas of training that need greater attention, and it offers some guidelines for future training programmes. The report discusses the fundamentals of helicopter flight, in order that the layman may gain some appreciation of what problems the pilot has to tolerate.
Several types of operations are then detailed with safety prescriptions for each one. Some causative factors in each operation are also discussed. The report then analyses the use of helicopters in aerial ignition systems. Of the several systems currently in use, it is clear that the helicopter drip torch is potentially the most hazardous, but to date there have been no serious helicopter drip torch accidents. Finally the report looks at crew deployment techniques, in particular, helicopter rappelling and helitack. The level of training and hazard awareness in these two operations is higher than was generally seen elsewhere, and provides a good example of how helicopters can be used safely and efficiently.

Throughout the report, reference is made to past accidents. These accidents show a fundamental lack of safe practice; a situation that would be improved with better training programmes. They also illustrate some of the diverse and disastrous results of poor training.

The report recommends that the Workers' Compensation Board of British Columbia should seriously consider setting up a series of training films, which, along with posters and leaflets, could be distributed to the various companies and organisations who use helicopters in the course of their operations. Transport Canada is now preparing a series of general training aids, and these will be made available to interested parties.
The author believes that by increasing the worker's awareness of the hazards inherent in all helicopter operations, many of the unnecessary accidents of the past may be prevented from reoccurring.
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DEFINITIONS

Helicopter

- a flying machine sustained by a power-driven screw or screw revolving on a vertical axis. (5:604)

   HELICOPTER - English
   HELICOPTRE - French

Helix (screw)       Ptero (wing) - Greek

Aircraft Accident

Any occurrence associated with the operation of an aircraft that takes place between the time any person boards the aircraft with the intention of flight and until such time as all persons have disembarked in which:

(a) any person suffers death or serious injury as a result of being in or upon the aircraft or by direct contact with the aircraft or by anything attached thereto.

(b) the aircraft receives substantial damage or is destroyed. (10:101)
Rappelling

Rappelling is a technique by which a person slides down a fixed rope, using the friction of the rope acting on some other surface, to control the rate of descent (4.).
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J.A. Dunster

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INTRODUCTION

The increasing need for fast and efficient transportation in today's working world has led to greater utilisation of helicopters. The use of helicopters permits efficient crew deployment, and allows greater operational flexibility. This is particularly important in forestry operations, where rapidly increasing demands on the resource, and rising costs, emphasise the need for a fast, efficient, and adaptable means of transport. However, the increasing use of helicopters in a wide spectrum of forestry operations has also created a diversity of hazards, many of which are not generally appreciated.

Discussions with the Workers' Compensation Board of British Columbia, early in 1978, indicated that two areas of helicopter use in forestry were of immediate interest: fire suppression, and prescribed burning. In recent years, fire suppression techniques have made increasing use of helicopters to enable rapid deployment of men and equipment into remote, inaccessible areas, thus greatly reducing the initial attack time. Similarly, the use of aerial ignition systems has radically changed prescribed burning techniques, allowing faster ignition and greater control of the area to be burned. During the several months spent analysing these two areas of helicopter use, the author
was actively involved with helicopters in fire suppression and prescribed burning operations, making field observations on the various aspects of each operation, and interviewing the people working with helicopters (pilots, ground crew, supervisors, and officials). The methods used to conduct the study are outlined in Appendix 5. This report is based on the experience gained in those months, and summarises the hazards that were observed and/or discussed.

With a view to increasing people's awareness of the hazards inherent in helicopter operations, the report is presented in four sections, each one emphasising a specific aspect of helicopter use.

SECTION I. The Helicopter
SECTION II. Safety In and Around the Helicopter
SECTION III. Aerial Ignition Systems
SECTION IV. Crew Deployment Techniques

Throughout the report, a black dot followed by numbers ( • 12,14,4.) refers the reader to past accidents, listed in Appendix 1. These accidents, all of which occurred in the last five years, reinforce the points mentioned in the text and clearly illustrate the potentially dangerous nature of even the most mundane helicopter operations.
SECTION I.

THE HELICOPTER
CHAPTER 1. TRENDS IN THE USE OF HELICOPTERS

Since time immemorial, man has wanted to fly, and over the centuries many people have tried to solve the riddle of flight. As early as 1505, Leonardo Da Vinci drew up a set of plans for a flying machine, but these plans were never put into action. By the end of the nineteenth century many people were working on the problem of flight, and rudimentary gliders had been successfully flown. On December 17, 1903 at an aerodrome in Kittyhawk, Northern Carolina, the Wright brothers, Orville and Wilbur, flew a biplane for just over 12 seconds, travelling 34 m. The era of powered flight had finally arrived.

From that time on, fixed-wing flight advanced rapidly, and by the time of the First World War, aeroplanes were relatively sophisticated, allowing the pilot to perform intricate manouevres. The helicopter, however, received far less attention. The first successful, public helicopter flight did not occur until 1938, in Berlin. The pilot of this first flight was Miss Hanna Reitsch (17:2). The machine, known as the Focke - Achgelis, made the first cross-country flight from Bremen to Berlin, a distance of 230 km.

Probably the best known figure in the evolution of the helicopter is Igor Sikorsky. He had experimented with helicopters since 1907, and after becoming successful in
fixed-wing design, he finally produced the VS300 helicopter. In 1941, Sikorsky set a new record, by remaining in the air for one hour and thirty-two minutes. The helicopter had finally come into being.

Even today, the helicopter receives far less attention than aeroplanes. Many of the rules and regulations applied to helicopters have been derived from fixed-wing operations, and are not strictly applicable to helicopters.

Figure 1. The trends in growth of population and accidents in the 1970's. (Canadian Registered craft). (20.)
Similarly, much of the theory of flight, tried and tested on fixed-wing craft, cannot be easily applied to rotary-wing machines. This discrepancy between the two forms of flight is reflected in the growth of the two populations (Figure 1).

In 1970, in Canada, the fixed-wing population was about 10,600 compared to a helicopter population of about 550; i.e. there were 20 aeroplanes for every helicopter. By 1977 there were 19 aeroplanes for every helicopter, still a considerable difference.

Considering that there were 20 times as many aeroplanes as helicopters, it would seem reasonable to expect the fixed-wing form of flight to have had more accidents. However, based on the average from 1970 to 1977, each helicopter accident (involving 10.3% of the population) corresponded to only seven fixed-wing accidents (involving 3.8% of the population). Figure 1 also shows the trends in fatal accidents. No allowance is made for more than one fatality in any one accident. The trends show that the percentage of accidents that were fatal in the two forms of flight was on the average about the same (12%). Over the eight year time span, the trend in fixed-wing flight, although fluctuating, was the same in 1977 as in 1970.
In helicopters however, the trend shows that the percentage of accidents that were fatal increased, despite the fact that the number of accidents per year fell from 12.3% of the population in 1970, to 6.6% in 1977. The reasons for this anomaly are not immediately clear, but it may be that helicopters today are being used in more demanding situations, which are inherently more dangerous. If this is so, a mistake on anyone's part is more likely to result in a fatality.

Figure 2 shows in greater detail the relationship between the growth in helicopter population, the total

![Figure 2. Trends in helicopter population and accidents. (20+)](image)
number of accidents, and the number of fatal accidents (Canadian Registered craft). Over an eight-year span, the helicopter population had doubled, but the total number of accidents per year was the same in 1970 as in 1977. Although the percentage of the population involved in accidents had almost halved, the number of these accidents that were fatal had more than doubled.

Figure 3 gives a breakdown of the number of operating hours, the number of accidents, and the accident rate per 10,000 hours, by Province.
rate per 10,000 hours by province. Figure 3 clearly shows that the number of hours flown does not necessarily indicate the accident rate. Quebec had over 200,000 hours of flying in 1975 and 1976, yet the accident rate per 10,000 hours was only 2.1. Saskatchewan had 14,700 flying hours in the same two years, one fourteenth that of Quebec, yet the accident rate per 10,000 hours was 6.8 - more than three times as high. This suggests that it is not the number of hours flown that matter, but possibly the conditions under which the flight takes place. Since the conditions of use are not known for either Province, it is impossible to state why the variation in the accident rates is so large. On the basis of the information in Figure 3, the hours flown cannot be taken as an absolute measure to indicate the safety or lack of safety in any one operation or Province.

Clearly, much work still needs to be done to bring these accident rates down. In the following chapters the fundamental principles of helicopter flight, several helicopter operations, and aerial ignition systems are all discussed.

Already, helicopters are being extensively used in forestry for aerial survey work, e.g. insect infestations
and topographical surveys; routine crew transfers and transportation of equipment; helicopter logging; and fire suppression and prescribed burning operations.
CHAPTER 2. HOW THE HELICOPTER FLIES

In this section the principles of helicopter flight are outlined, together with some discussion of the practical problems involved in certain manoeuvres. An understanding of these principles and problems will aid the reader to appreciate why certain actions should be executed during the use of helicopters. For a more detailed discussion of the principles of helicopter flight, the reader is referred to the "Basic Helicopter Handbook" published by the Federal Aviation Administration in the United States.(22.) In the following paragraphs some of the fundamental components of flight are briefly defined.

Any surface designed to produce lift or thrust when air passes over it is termed an aerofoil. In aeroplanes (fixed-wing craft) the wings and propellers are the aerofoils, while in helicopters (rotary-wing craft) the main and tail rotors are aerofoils. Both fixed wing and rotary wing craft need the passage of air over these aerofoils to gain lift or thrust. The difference between the two aircraft types is that a fixed wing craft uses the propellers to drag the wings through the air and thus create lift, whereas, in a rotary wing craft, rotation of the wings (rotors) produces lift and thrust in the direction desired.
In most North American helicopter designs the main rotors rotate counter-clockwise, while in European and Russian designs the main rotors rotate clockwise. The area that the rotors occupy is called the rotor disc. Lift occurs at 90° to the rotor tip path; thus, the direction of travel is a function of the direction in which the disc is tipped. The lift generated by the passage of air over the aerofoil can be altered by changing the angle of attack and the pitch of the rotor blades. Figure 4 shows the relationship between the angle of attack, pitch and relative wind.

The chord line is an imaginary line from the leading edge to the trailing edge of the aerofoil. The acute angle between the rotor blade chord line and the rotor's plane of rotation is the pitch angle. This angle can be varied by use of the collective and cyclic controls in the cockpit. The angle between the chord line and the direction of the relative wind is the angle of attack. The angle of attack is not the same as pitch angle, unless the relative wind is parallel to the plane of rotation (Fig. 4). Increasing the pitch angle will also increase the angle of attack and vice versa. However, increasing the angle of attack will also increase the drag force; that is, the force resisting the movement of the aerofoil through the air. It is this drag force that causes a drop in the rotor revolutions per minute.
Figure 4. The aerofoil and its flight components.
(RPM). Hence to gain extra lift the rotor speed has to be maintained and this calls for additional power from the engine.

The relative wind is the wind's direction relative to the aerofoil. Relative wind is parallel and opposite to the direction of aerofoil travel. Thus, when the helicopter hovers in a no wind situation (still air) the relative wind is entirely due to the rotation of the rotor blades. Hovering in a wind, the relative wind is the sum of the wind direction and the rotation of the rotor blades. In forward flight the rotor blade movement and the movement of the craft through the air creates the relative wind. Hence increased relative wind gives increased lift. Generally, the pilot will aim to keep the rotor speed constant and change the lift force by changing the angle of attack, rather than boosting the power and thereby turning the rotors faster to increase relative wind.

The effects of air density on lift

The amount of lift available is dependant on the density of the air. Denser air increases the lift and drag. Less dense air decreases the lift and drag. Air density is affected by the following factors:
1. Altitude: density decreases with increasing altitude.

2. Air temperature: air expands on heating (i.e. warm air is less dense than cold air).

3. Decreasing pressure: air expands as pressure decreases and so becomes less dense. Hence, atmospheric pressure affects air density.

4. Relative humidity: moist air is less dense than dry air. Also, warm air can hold more moisture; therefore, warm humid days lead to low density air.

Since air density may decrease with a change in the above factors, the pilot has to increase the angle of attack in order to maintain the lift. To do this the pitch angle must also be increased, resulting in greater drag and decreased rotor RPM. Thus, more power is needed to maintain the RPM. Both the pilot and the people directing the helicopter operation should be aware of these conditions, since the additional power needed to maintain rotor RPM may be beyond the capability of the machine. This is especially important if the machine is operating at, or close to, its maximum gross weight. (● 11.)
Translational Lift

Contrary to the popular conception, there are many times when the helicopter cannot lift off the ground vertically. This is because the helicopter often does not have sufficient power to generate more lift when loaded and/or operating at altitude. Normally, the helicopter lifts off the ground and then flies forward, building up its airspeed to gain extra lift. Translational lift is the additional lift obtained due to the greater mass of air per unit time flowing over the rotors as a result of the forward flight (i.e. increased relative wind). Translational lift is present with any horizontal movement, but becomes most noticeable at airspeeds in excess of 24 km/h. This extra lift is termed effective translational lift and permits increased helicopter performance.

Since most helicopters need this translational lift to gain height, the design and layout of landing areas should make due allowance for this.

Ground Effect

When a helicopter is hovering close to the ground, the rotor blades displace air down through the rotor disc faster than it can escape from beneath the helicopter. This
forms a cushion of air between the helicopter and the ground and is referred to as 'ground effect' (Figure 5). The ground effect helps to support the helicopter in a hover, and is effective at a height of half the rotor disc diameter. The helicopter leaves the ground effect at an airspeed of 5 to 8 km/h. This same effect causes loose objects to be blown about when the helicopter is hovering and, in some cases, the displaced air forms eddy currents, causing a suction force to be present. This suction is potentially very dangerous, since it can easily cause loose objects to be drawn up into the rotors (Chapters 4, 9).

( • 1, 8, 9, 10.)

Figure 5. Ground effect.
From the preceding discussion it is clear that certain stages in the operation of a helicopter are more critical than others. While fixed wing aircraft can usually glide to the ground, the helicopter relies on the rotation of its rotors to maintain its altitude. In the event of an emergency (such as an engine failure) the engine is disengaged from the rotors. As the helicopter settles through the air, the upward flow of air causes the rotors to rotate, allowing some lift to be maintained. This is called autorotation. For each model of helicopter an altitude versus airspeed chart is prepared, indicating to the pilot at what altitude and airspeed he can safely make an autorotative landing. Figure 6 shows a typical example.

Figure 6. Airspeed - Altitude chart.
Any combination of altitude and airspeed falling within the shaded areas is to be avoided. These areas are often called the "Dead Man's Curve". Recognition of this problem will help in appreciating the problems involved in operation of some aerial ignition systems, discussed later in this report (Section III).

Because the main rotors rotate counter-clockwise, the fuselage tends to rotate in a clockwise direction. This is in accordance with Newton's third law of motion: "To every action there is an equal and opposite reaction". This tendency is known as torque.

Figure 7. The tail rotor and the effects of torque. (22.)
To counteract this torque, an auxiliary rotor is placed at the end of the tail boom (Figure 7). This rotor is usually called the tail rotor or anti-torque rotor. It develops thrust in opposition to the torque of the main rotors. The thrust is controlled by means of foot pedals in the cockpit. If the torque is neutralised the direction of travel remains constant. If thrust is increased the craft turns to the left; if thrust is decreased the craft turns to the right.

The Turbine Engine in Helicopters

Most modern helicopters are equipped with turbine engines, as opposed to the older piston engines. After a flight, the helicopter will be left at ground idle to cool the engine. The time needed to cool the engine is commonly about three to four minutes minimum. This cool down period is very necessary for the helicopter, since it not only prolongs engine and component life, but it also reduces the chances of engine failure due to seizure of the bearings and other moving parts. This cool down period (technically referred to as ground idle dwell time) should be allowed for in scheduling helicopter operations where the helicopter has to be shut down as a part of the operation.
SECTION I SUMMARY

Between 1970 and 1977, the population of Canadian registered helicopters doubled; the percentage of the population involved in accidents (per year) halved, yet the percentage of these annual accidents that involved fatalities, increased. In the years 1975 and 1976, British Columbia had the third highest accident rate per 10,000 hours at 3.6 (after Saskatchewan - 6.8 and Alberta - 5.6), and flew the second highest number of helicopter hours (after Quebec).

Helicopters generate lift by rotation of an aerofoil (main rotor) and maintain direction by utilising the thrust of the tail rotor to counteract the torque of the main rotors. Varying this thrust alters the direction of travel. Since the helicopter generates lift by the passage of air over its rotors, air density is a critical factor in helicopter operations. Air density is affected by altitude, air temperature, decreasing pressure, and relative humidity. All helicopters reach a limit where they are unable to take off vertically, and at this point they depend on translational lift to gain altitude. Translational lift results from a faster airspeed which allows more air per unit time to flow over the aerofoil, thus increasing the relative wind.
Translational lift is most noticeable at an airspeed of 24 km/h or more. The need for translational flight is often a critical factor in the layout of landing sites.

When a helicopter hovers close to the ground, the rotor blades displace air down through the rotor disc faster than the air can escape from beneath the helicopter. This forms a cushion of air, referred to as ground effect. Ground effect is present at a height of approximately one half the rotor disc diameter, and at airspeeds of less than 5 to 8 km/h.

This rotor downwash is also responsible for creating a suction force, and in some cases creates an extremely dangerous hazard in that it will easily draw loose articles up into the rotors.

Certain combinations of airspeed and altitude are unsafe for helicopter operations, since the helicopter is unable to make a safe autorotative landing in these conditions. Each helicopter type has its own particular characteristics for operation. These characteristics are summarised in an airspeed - altitude chart, commonly called the "Dead Man's Curve".

Understanding the fundamental principles of helicopter flight will enable the people directing helicopter use, to gain a greater appreciation of the pilot's objectives.
In this section the safety of the people working in and around the helicopter is discussed. Most workers seem to have had some fundamental helicopter safety training, yet reference to Appendix 1 shows that accidents still happen in which the basic safety precautions were not observed. These accidents were either a result of poor education about the hazards, or failure to observe the precautions learnt. Basic safety precautions cannot be overemphasised, and everyone who has cause to go near a helicopter should understand the reasons for these precautions and the consequences of not observing them.
CHAPTER 3. TRANSPORTATION OF PERSONNEL

Under no circumstances should anyone be close to a helicopter without first having a briefing in basic safety procedures and special features of the machine being used. (For example, the Sikorsky S-58 T has the exhaust at the front of the helicopter.) The following points are fundamental to a safe operation and should be followed by everyone working near helicopters.

ENTRY

1. Only approach the helicopter when the pilot signals that he is ready for you to board the craft.

2. Always approach from within the pilot's field of view and stay in his field of view at all times (Fig. 8).

3. Prior to approaching the helicopter, check the slope of the ground, and always approach from the downhill side (Fig. 9). (● 14.)

4. Prior to the approach, insure in a final check that any headgear worn is fastened down with a chinstrap. If it is not, hang onto it or carry it separately. Similarly, all loose clothing, paper and other light objects should be secured. (● 8,9.)
Figure 8. The Pilot's field of view.

Figure 9. The correct approach path.
5. In approaching the helicopter, it is necessary to crouch to avoid being hit by the main rotors. If it is clear that the pilot is shutting down the helicopter, do not approach (unless specifically signalled to by the pilot) until the rotors have come to a halt. As the rotors slow down, they will droop leaving less clearance between their tips and the ground. Similarly, it should be realised that the main rotors are mounted on a pivot and in a gust of wind can dip much closer to the ground than might normally be expected. Bearing in mind that the tip velocity of the rotor blades is approximately 644 km/h (400 mph), one's chances of survival, if hit, are slim. Plates 1 and 2 illustrate how the main rotors on a Bell 206 Jet Ranger can come to within 1.6 m of the ground solely by taking up the slack in the pivot. A gust of wind could lower the tip further.

6. Once at the helicopter, open the door, step into the craft and sit where the pilot indicates. The door should be closed gently but firmly. Never slam the doors since they are only made of a thin alloy shell and distort easily. The seat

belt should be fastened and left on for the duration of the flight. If movement within the helicopter is anticipated once in flight, it should be discussed with the pilot prior to take-off since, once in flight, movement may alter the centre of gravity, causing unnecessary problems for the pilot.

7. Unless loading cargo into the storage areas, never move towards the rear of the helicopter. If cargo is being loaded, be aware of the tail rotor. It will be virtually invisible when turning and will kill or maim anyone walking into it.

IN FLIGHT

1. Once in the helicopter, it is essential not to touch any of the controls. This is especially important if sitting in the front seat of a dual control helicopter. (● 26.)

2. All maps and documents should be secured in flight and kept out of the pilot's way. All loose materials should be kept away from the windows since they may be sucked out and cause serious damage to the rotors, or be ingested into the turbine engine, leading to engine failure.
3. Only smoke with the pilot's permission. Never smoke during take off and landing.

4. While it is inadvisable to distract the pilot's attention unnecessarily, there may be certain times when you feel that an impending hazard has been missed by the pilot. In this case you should bring it to his attention as soon as possible. Pilots are not infallible. (● 15.)

5. Never open the door during the flight. Open doors considerably alter the flight characteristics of the helicopter and the pilot needs to be able to correct for this in advance.

6. Be aware of the heating system in the helicopter. Hot air is blown over the windows to prevent fogging. Ask the pilot before opening any windows.

7. Don't look at the rotor blades overhead; it may cause discomfort. (see also Chapter 9).

8. Wear ear protection whenever exposed. (24:33.18). (See Chapter 9).

9. Do not try to clean the perspex windows. They scratch easily.

10. Read the notices and signs on the windows and seat backs. They are there for your benefit.
1. Once out of the craft, place the safety belt on the seat, and shut the door.
2. Walk away from the craft on the pilot's signal.
3. Stay within the pilot's field of vision and walk away in a downhill direction. Never walk away uphill. (See Figures 8 & 9)
4. At all times stay away from the rear of the helicopter and its tail rotor.
5. In some cases it will be impossible to walk away. In this situation crouch or sit by the skid until the helicopter has lifted off. If any equipment has been unloaded make sure that it is secured using the heavier objects to weigh down the lighter ones. Do not forget that the rotor wash will tend to suck objects up into the rotors.

Exit at a Hover

In certain cases it may be necessary to exit from the helicopter while it is in the hover. The craft will either be hovering a few feet above the ground, or with the front end
(toe) of one or both skids against a hillside.

The procedure for exit on the hover is as follows:

1. At the pilot's command, unfasten the safety belt and prepare to exit.
2. Open the door and slowly and smoothly climb out onto the skid.
3. Once on the skid, recheck with the pilot that all is well and then slowly lower off the skid onto the ground.
4. Once on the ground it is usually wise to crouch or sit until the helicopter has left.

Stage 3 is critical. Under no circumstances should one jump off the skid. The force acting down on the skid as one jumps may be enough to upset the balance of the helicopter and roll it over. Also, prior to exit it is wise to check the conditions on the ground. Hover exits are made only in the most difficult locations, and often it would be hard to get on board again. Wherever possible, hover exits are to be avoided in favour of a conventional landing area.
Discussion of Chapter 3

The points listed above for entry and exit are well known and widely documented. Yet, as can be seen from the accident citations in Appendix 1, accidents still occur. The reason for this would seem to be largely a matter of poor training. During the author's discussions in the summer of 1978, one of the main causes of accidents was attributed to inadequate training of the ground crews.

Most companies and the Forest Service have their own training programmes. These programmes consist of narrated slide shows, illustrating most of the basic safety points, followed by a visit to a helicopter to familiarise the trainees with the safety procedures previously seen on the slides. The standard of these training programmes varies. Some are well thought out with clear lectures and emphasis on the important points. Others are poor, hastily put together and rely on the trainee picking up the points out in the field.

A further cause of accidents is the use of pick-up crews, which are made up of people who are conscripted for fire suppression work. Members of these crews are particularly vulnerable to accidents. Some may have had previous exposure to helicopters; some may have attended a training course many years ago but never had the chance to put the knowledge gained into action; and some may not know the first thing about helicopters. Whatever the case, the supervisor or the pilot should take the time to briefly outline the basics of
helicopter safety. This should be done well before the crew has to board the helicopter, not as it is boarding. The supervisor should also make it clear that the cost of a mistake is high, both materially and in terms of life.

Possibly one of the main factors leading to accidents around helicopters is the great haste with which operations are often conducted when helicopters are being used. If the crew were driving out to the fire in a pick-up truck, it is likely that they would load the truck up and drive off with care. The whole operation while probably carried out at a faster pace than normal, would not be done impulsively. However, a different situation is seen when a helicopter is used. For some reason many people become excited at the sight of a helicopter. It may be the thought of a helicopter ride or it may be that they are in awe of helicopters. For whatever reason, this excitement seems to make many people act irrationally. In some cases near panic was witnessed where crews were about to be picked up by the helicopter (especially on the first trip).

Listed below are some of the possible reasons for this panic and haste.

1. Crew members know that helicopters are expensive; so they rush around trying to speed up the operation to avoid wasting helicopter time.
2. Crew members remember the lecture on safety and not wishing to expose themselves for longer than necessary to the hazards, they rush toward or away from the helicopter. Similarly, the crew may actually be a little frightened of the machine and its power, and this fright may outweigh common sense.

3. Some people simply forget certain safety precautions. Accidents due to forgetfulness are hard to overcome entirely.

4. A few people find the experience of flying very exciting. This excitement may cause them to forget the safety procedures, or it may cause them to act irrationally.

5. Some people may have been on standby for a long time and the thought of at last getting out to the fire causes them to rush and forget basic safety precautions.

Whatever the reason for the rush and haste around helicopters, better training programmes would go a long way to preventing some of the accidents. More emphasis should be placed on the outcome of mistakes. Many times the author saw the supervisory personnel rushing the crews to get them out to the fire. This
rush passes on to the crewmen, and may contribute to the
general excitement around the helicopter. The life of a
crew member is worth many times the damage caused by fires,
no matter what the circumstances. Both the crew members
and the supervisory personnel should be aware of all the
safety procedures. There should be no cut-off point for
this. It should not matter whether it is a fresh crew member
or the regional manager. One and all should be briefed
again and again on the safety points. Similarly, the people
directing the operation from the base should make due
allowance for the safety of the personnel working in and
around the helicopters. Haste and panic at the supervisory
level will inevitably be passed on to the crew, and more
often than not, it is the crewman who suffers. At all times
pilots and supervisory personnel should go out of their way
to set a good example.

One way to have better training would be to make use
of slides of actual accidents. People may remember far more
easily a photo of a smashed hard hat and a ruined tail rotor
than a photo of a tail rotor and being told to stay away.
This approach may sound callous, but if it saves lives it will
be worthwhile. This aspect of crew training is one of the
major areas that the WCB could contribute to. A series of
graphic slides, possibly a film in cartoon style of the
consequences of mistakes, and a series of posters to put up
on fire sites, would all help to educate people working near helicopters. Using such methods people will be made aware of the lethal potential of their haste and short cuts.

Exit at a Hover

Air regulation No. 511 states: "Except as otherwise authorised by the Minister, no person shall enter or attempt to enter any aircraft in flight or leave or attempt to leave any aircraft in flight except for the purpose of making a parachute descent or give upon any aircraft in flight any gymnastic or other like exhibition." (T8:511)

Technically if the helicopter does not have both skids on the ground then it must be in a hover or flight. Hence, strictly speaking, exits at the hover or from one skid landings are illegal. However, the advantage of the helicopter is its ability to get into remote places and enable people to get much closer to their objective faster than would be possible by conventional means (such as walking in).

In some cases the helicopter will not be able to land next to the objective, and the nearest available landing site may be several kilometres distant. In these cases an opportunity may well present itself for a hover exit or a one skid exit, which is at a location much closer to the objective. It would be unrealistic to suppose that by regulating against
this type of exit it will cease to occur. Out in the field there are no inspectors to enforce this regulation and if the pilot and crew feel that they can make such a manoeuvre without endangering themselves or the helicopter, then it is unlikely that they would choose the alternative of landing at a location further away and walking in to their objective. It would be far more practical to adopt an educational approach aimed at both the pilots and the crew members. Such an approach would make it quite clear that while this type of exit is not favoured, it may have to be used in some conditions. The proper procedure would then be outlined and the potential hazards clearly shown.
CHAPTER 4. TRANSPORTATION OF EQUIPMENT

Since the helicopter is such a versatile machine, it is commonly used to transport cargo into remote areas. The cargo is either loaded into the helicopter in small, easily handled units, or it is carried as a sling load suspended beneath in helicopter. In either case there is a definite procedure which must be followed if accidents are to be avoided.

Loading Cargo Into the Helicopter

Usually, the crew and cargo will be waiting at the landing site for the arrival of the helicopter. Once it has landed, the pilot may shut down the machine in which case loading is less hazardous since the danger of the spinning rotors is removed. However, it is not unusual for the pilot to touch down and maintain the helicopter engine at flight idle while the machine is loaded. In either case, safety precautions should start before the helicopter arrives.

1. Prior to the arrival of the helicopter, the cargo to be loaded should be neatly and systematically stacked by the side of the landing zone. Care should be taken to see that light articles are secured. (● 8,9.)
2. One person should be responsible for loading the machine and should decide prior to loading exactly how much and which part of the cargo is to be loaded (if more than one flight is planned). Once the pilot has touched down, the loading supervisor should check with the pilot to confirm the destination of the cargo. He should also check to see if any flight conditions prevail which might alter the payload of the helicopter. (

3. The loading supervisor should know the exact weight of the cargo and should notify the pilot of this figure.

4. Entry to and exit from the helicopter should follow the standard procedures outlined in Chapter 3.

5. The cargo should be loaded so that the weight is evenly distributed within the helicopter. Uneven loading alters the centre of gravity, causing flight problems for the pilot. Similarly, the load should be securely located to prevent shifting during the flight.

6. Bundle tools, poles, etc., so that they can be easily handled by one man. Sharp edges and points should be covered.
7. All equipment carried in the crew quarters should be tied down and kept clear of the flight controls. ( 2.6.)

If long-handled tools are being loaded into the helicopter, the loading person must remember that carrying such objects on the shoulder is strictly forbidden. Crouching down to avoid the main rotors, causes any object over the shoulder to be tipped up, possibly fouling the rotors. The correct method is to carry the tools horizontally at waist level.

The unloading procedure is the exact opposite of loading. In some cases the safest procedure is to unload the cargo next to the helicopter and pile it securely. One person waits with the cargo until the helicopter has left the area. The cargo is then moved elsewhere. This procedure cuts down on the exposure time, by reducing the amount of walking to and from the helicopter. It also reduces the tendency of some people to stand by the helicopter and throw objects to the edge of the landing zone. This practice is extremely dangerous, bearing in mind that the rotor wash may cause items of cargo to fly up into the rotors. This may occur even with such things as axe handles, shovels and other heavy objects. ( 1, 8, 9.)

Knowing the exact weight of the cargo is very important. By knowing what the helicopter can safely transport, the supervisor is able to maximise each load. This cuts down on
the costs, since fewer trips have to be made. It also prevents overloading the helicopter, thereby preventing accidents. The customer will always want to maximise the load, but it is unwise to pack more and more equipment into the cargo pile and still accept it as being the same weight. Similarly, it is poor practice to estimate weights of cargo, hoping that the estimate will be near enough. All too often the customer puts extra pressure on the pilot to take the load at its stated weight, even if it is obviously more. The pilot is placed in an unenviable position. If the pilot refuses, the dissatisfied customer may spread the word that this company is not cooperative.

Alternatively, the pilot agrees to take the load because he trusts the customer to be honest about the load's stated weight; because he is going out of his way to please the customer; or because he feels that he can probably get away with the extra load by pushing the helicopter a bit more. This latter case may lead to accidents. Often the pilot will not have sufficient power to complete the necessary manouevres for safe flight, resulting in a crashed helicopter.

(● 11,12,13.)

Many people feel that it is the pilot's responsibility to ensure that the loads he takes are not too great, but under pressure from the customer some pilots find it very hard to refuse. Once again, greater understanding by the customer
and crew of the problems that the pilot has in flying the helicopter, and the reasons for not doing certain things, would go a long way to preventing overloading accidents.

External Loads

Some helicopters are equipped with racks or baskets on the outside of the fuselage in which small objects can be stored. When loading these racks or baskets, care must be taken to ensure that all loose articles, such as tent guy lines, ropes, hoses and lanyards, are tied down.

The more common external load is a sling load, which allows transportation of large bulky loads. Sling loads are attached to the cargo hook beneath the helicopter, which is remotely controlled by the pilot so that he can jettison the load at any time. In many ways slinging is considerably safer than unloading and loading the helicopter, since the exposure time for loading personnel is less. The helicopter can fly into the site and hover while the hook up of the load is carried out. At the destination the load is gently lowered to the ground in a hover, and released. The following procedures are essential to the safe operation of sling loading:
1. If using a cargo net, the heavier objects should be placed in the centre of the net. When the corners of the net are drawn together and clipped into the loading ring, care should be taken to see that all loose objects are secure and will not come loose in flight.

2. Square or oblong shaped loads tend to rotate in flight. If possible they should be carried in a net, which will reduce the tendency to spin. If the load has to be slung without a net, four points of attachment will give greater stability on large loads. The stability of the load in flight is a function of the angle formed by the ropes suspending it. If the angle between the ropes exceeds 90\degree, the load will tend to fly as it gyrates and swings beneath the helicopter. (\#17.) Figure 10 illustrates the right and wrong way of attaching the ropes. Reference to Appendix 1, accident number seven, shows the details of an accident caused by such an unstable load. It was determined that the angle of the ropes on the angle iron exceeded 90\degree, causing the load to swing around and eventually hit the tail rotor. If spinning cannot be avoided, a swivel
Figure 10. The right and wrong way to attach ropes to a sling load.

should be used between the cargo hook and the lanyard ring. Failure to use a swivel may result in the lanyard breaking.

3. Where possible, the hook-up man should have the option of wearing goggles to protect his eyes.

4. If the hook-up man is wearing a hard hat he should have the chin strap on. No hat at all is safer than a loose one.
5. If a marshaller is available, he can direct the pilot onto the load. If not, the hook-up man should consult with the pilot to agree on the methods to be employed in the hook-up procedure.

6. Once the helicopter is in place, hovering over the sling load, the hook-up man should first of all reach up and touch the cargo hook with the ring on the end of the lanyard or sling. This will ground the helicopter dissipating any static electricity that may have built up in flight. On no account should the hook-up man touch the helicopter before it has been grounded; the force of static electricity has been known to cause death. During the operation, the hook-up man should not try to guide the helicopter onto the load. This may cause flight problems for the pilot, which he may not be able to correct in time to avoid an accident.

7. The hook-up man, once he has grounded the helicopter, clips the load ring into the cargo hook of the helicopter, checks it, and then moves forward and to one side into the pilot's field of view. Since the pilot usually sits on the right hand side, it is recommended to move to the right.
8. The helicopter lifts off and takes up the slack in the line, then slowly lifts the cargo off the ground, and flies away. The helicopter should be able to fly into the wind to gain lift (see Section I) without having to fly over men or equipment.

9. At the destination all personnel should stay clear of the drop zone until the load has been set down on the deck. If a marshaller is present, he should stand with his back to the wind and guide the helicopter into the landing area.

To allow a maximum payload and safety margin, the sling load is normally transported without any passengers on board.

Often the hook-up man will be on his own, without the help of a marshaller. In many helicopters there is a mirror situated outside the cockpit, just below the pedals. The pilot is able to watch the hook-up procedure via this mirror.

If a marshaller is directing the operation, the pilot may make use of the mirror and the marshaller. The marshaller should bear this in mind, and in no circumstances should he make any signals other than those recognised in the marshalling code. The marshaller should maintain the signals throughout the operation regardless of whether the pilot is watching him. The pilot has more than enough to do watching the marshaller, the hook-up man and flying the helicopter.
As in internal loading, it is vital to tell the pilot the exact weight of the load. In sling loads the clearance beneath the helicopter is reduced; hence the helicopter has to fly at a higher altitude to clear the same obstacles as before. If the environmental constraints put the helicopter at its performance limit, it may be extremely hard for the pilot to clear these obstacles. (● 2,3,4,5,6.)

Point 3 states that wherever possible the hook-up man should have the option of wearing goggles. This should not be made mandatory, however. Firstly, mandatory use of goggles would mean that the men in the field would have to carry a pair of goggles around, and this would be just one more item of equipment to look after. Moreover, most of the goggles currently available do not stand up to the conditions encountered in the field. They are easily scratched and often fog up. Only the better quality goggles overcome these problems, but considering the high loss rate of small items in the field, the cost of distribution is unrealistic in most cases.

Despite this, goggles are useful and if individuals can be trusted to look after a pair and use them when needed, this would probably help the hook up operation. In some circumstances the sling load may be attached at the end of a
long lanyard (30-61 m). Using this method, the pilot can lower the cargo into a confined space without having to put the helicopter near the obstructions. Long-lining is usually done with less than the maximum payload, since the helicopter has to take off, relying on its engine power, in a vertical mode to take up the slack in the line. The technique creates a few problems for the pilot and a good deal of skill is needed to control the load underneath the helicopter. The load tends to act like a pendulum, with the force resulting from the swinging load, acting directly on the helicopter and creating flight stability problems. Inexperienced pilots will generally have problems in keeping the load steady as it is lowered to the ground. In helicopter logging the problem is the same, but here the pilot spends many hours gaining intensive experience. Long-lining is not common in routine helicopter operations, hence, some problems might be expected with pilots inexperienced in this technique. However, operational experience is the only satisfactory way for pilots to become proficient. When the long line is hooked up with the helicopter on the ground, care must be taken to ensure that the lanyard passes under the skid. Failure to do this will mean that the load will be acting over the skid once airborne and will tend to roll the craft, with potentially lethal results. (2,4.)
On the ground great care should be taken to see that all nets, lanyards and ropes are handled carefully. All are very light and easily sucked into the rotors. The material used for lanyards is much discussed and various types are currently in use. Hemp or sisal-based ropes should only be used when new and should be checked regularly. The danger is that if the rope breaks under load, it will snap back into the rotors, in flight probably into the tail rotors, and in a hover into the main rotors.

The ideal rope would be one that has good shock resistance with a limited amount of stretch. A non-stretch rope will transmit the shock load directly to the airframe. A rope with too much stretch will be like an elastic band and will induce bounce in the helicopter. If a lanyard has to be made up in the field, it should have a non-tightening loop at the end which attaches to the cargo hook. Generally it is better to use the slings and nets provided by the helicopter company.

For a more detailed review of sling loading, the reader is referred to the American National Standard for Rotorcraft External Load Operations. (B30.12) in which a detailed analysis is given of the various slinging methods and the equipment to be used. (1.)
Transport Canada Air Regulation 800 states:–

1. "Explosives and other dangerous articles or substances shall not be carried on board any aircraft except as authorised by the Minister.

2. No person shall send or take upon any aircraft any explosives or other dangerous articles or substances without distinctly marking their nature on the outside of the containers thereof or otherwise giving notice thereof to the person in charge of the aircraft, or the person whose duty it is to receive such goods on board."

Clearly the versatility of the helicopter makes it a good machine to use for transporting explosives to remote areas for specialist operations. However, in order to be able to legally do this the helicopter operator has to apply to Transport Canada for a waiver on regulation 800. This waiver can be obtained either on a short term basis or for several months if an amendment is written into the operations manual.
At the time of writing, Transport Canada is revising and updating the rules and regulations for transport of dangerous goods. The Dangerous Goods Act is presently before Parliament. This new act comprises separate sets of regulations for land, air and sea. Much of the new act will be based on the regulations of the International Air Transport Association. In the forestry context, the need is usually to transport either explosives for blasting in road construction and other large scale projects, or for the transportation of primacord for blasting fire line. In either case, both the explosive and detonating mechanisms (Caps) are needed. It is generally thought by forest workers that it is prohibited to transport explosives and caps together, but this is not so. A well defined set of drawings exist from which small tote boxes can be made up, to allow the transportation of small amounts of explosives and caps in aircraft. The main point to remember is that the two should never be stored together. The caps are kept in one box and the explosive in another. Electric blasting caps have to be protected from stray electric currents, radio frequency energy and other electrical energy sources. This is achieved by the use of a Faraday Cage, or by wrapping the box in aluminium foil.
In flight, the tote boxes should always be secured. The carriage of inflammable fluids such as gasolene or stove fuel is not permissible when explosives are on board. Similarly, only the people necessary to the blasting operation should be transported with the explosives. If at all possible, they should fly in on a separate trip.

Several types of storage facilities are currently approved by Transport Canada and the Explosives Branch, Department of Energy, Mines and Resources. Application to these authorities will reveal the procedures necessary to secure approval to transport explosives.
Helicopter landing sites fall into three basic categories: heliports, helispots and helipads. Heliports are permanent landing sites and are laid out in accordance with predetermined criteria. Most are close to civilisation and are easily accessible by road. They are commonly the loading sites for crews and cargo being ferried out to the field. Helispots are clearings without road access in which a helicopter can safely land. In some cases, the ground will be unable to support the weight of a helicopter, and a supporting structure, termed a helipad, will have to be built to prevent the skids from sinking into the ground.

The design and layout details of helicopter landing sites are straightforward and in many ways mundane. Yet, many accidents are caused by lack of attention to these details. The information presented in this chapter outlines the fundamental criteria needed to provide a safe and functional landing site. As with all other helicopter operations, understanding why certain criteria have to be met should help in preventing future accidents.
1. **Heliports**

Transport Canada publishes a small manual entitled "Heliport Design Criteria". A brief discussion will be included here, but for greater detail the reader is referred to this publication. (19.)

A helicopter needs to have sufficient clearance at a landing site to fly forward and gain translational lift, prior to gaining altitude (Section I). When a design plan is drawn up for a heliport, consideration must be given to how much traffic the site will receive, which helicopter types will be used, and the characteristics of the air in the proposed location. The latter is important in allowing for air turbulence due to surrounding buildings and other structures. Having selected the location, the landing site is usually built out of a concrete pad, although a well laid out wooden deck structure is as good, but may be slippery when wet. The minimum width should be at least twice the rotor diameter of the largest helicopter likely to be using the heliport. Ideally the minimum length is 122 m but this may be reduced if the approaches are free from turbulence and obstructions.

Most helicopters can land in a cross wind if it is not too strong, but they need to take off into the wind.
Hence it is good practice to have two approach paths at 180° to each other so that the pilot has an option if the wind direction is variable. A wind indicator is mandatory at heliports and should be clearly positioned so that the pilot can easily see it. The actual landing site is usually marked out as shown in Figure 11.

2. **Landing Sites in the Field**

The ideal landing site out in the field (Figure 12) is an exposed knoll. By clearing the surrounding area, 360° access is available. Ridges provide a reasonable alternative, but care must be taken to note the wind characteristics around such sites.

Landing sites should have a minimum clearance of twice the rotor diameter or at least 18 m. This will allow only 3 m clearance on each side for such as a Jet Ranger. Larger helicopters demand at least 30 m clearance to operate safely. If the wind direction is constant, the entry and exit paths can be extended to facilitate landing and take-off. Otherwise two approach paths should be provided at 180° to each other, or alternatively, greater clearance all around should be created.
Figure 11. The layout and marking of a Heliport. (19.)
Figure 12. The ideal layout of a landing site in the field.

The actual landing zone is built in the middle of the clearing. If the ground is firm enough to support the weight of a loaded helicopter, no supporting structure (helipad) is needed. Loose materials and vegetation are cleared to form
an 18 m clear area around the landing zone. The landing zone should be at least 4 m by 4 m, level and free from any obstructions. The site should be organised so that people coming into and out of the site know exactly where to go, and where to store equipment. Wind indicators should be present. These can easily be made by lashing a length of brightly coloured flagging tape onto a stick, and firmly planting this in the ground some distance beyond the landing zone. This wind indicator also provides the pilot with a visual reference by which he can judge his height above ground.

In many cases the surface of the ground will only be marginally capable of supporting the helicopter, or the ground may be uneven. In these conditions a supporting structure, referred to as a 'helipad', has to be built. The exact nature of helipad construction will vary from place to place depending on what materials are available at the site. However, the basic method of construction is similar in most cases. The four basics to consider are:

1. the helipad must be stable.
2. the helipad must be level.
3. the helipad must be strong enough to support the weight of a loaded helicopter.
4. the helipad must be free from snags and obstructions.
Usually logs from the cleared trees are used to form the initial structure. Two 3.6-m poles of similar size are laid down parallel to the prevailing wind and about 3 m apart. More poles are then laid across these two side poles to form a solid pad. The cross poles should be either notched into the side poles or secured by spiking or lashing to prevent movement. Ideally, there should be six cross poles forming the deck. In many cases there will not be enough materials or time to construct such an elaborate pad. The minimum requirements are two side poles and two cross poles. If only two cross poles are used, care should be taken to ensure that they are no more than 1.8 m apart, since on a Jet Ranger the standard skid is only approximately 2.4 m long. Larger helicopters will need larger and sturdier pads.

Figure 13 shows one way of constructing a helipad. Plate 3 shows an example of a rudimentary pad, built on a steep slope out in the field. Note the cleared trees in the back. The logs are notched into each other to prevent rolling and the two cross members are correctly spaced. The original construction of this pad had the cross members too far apart and the helicopter could not land on the pad. The front cross member was then moved back. Note that the pad shown in Plate 3 is fairly level, solid, and built so that the tail rotor is downslope and clear from any obstructions. Since
Figure 13. The layout of a helipad.

Plate 3. A rudimentary helipad.
this ridge was only about 9 m across, access was no problem, and exit was simplified since the pilot could utilise the sharp drop off at the sides to gain translational lift.

The problems involved in helipad or helispot construction originate in lack of attention to detail. Reference to the accidents in Appendix 1 shows that it is not uncommon for helipads to collapse either partially or totally, or for the pad to be built with a slope on it, causing the helicopter to slide off the pad. (18,19,20,21,22.) Loose materials, and people walking into the rotors due to the restricted space around the landing site, are always problems. (8,9,14.) Once again the main problem seems to be that the people building the landing sites do not receive sufficient training. More visual forms of training, such as posters and handouts, would perhaps better educate the crews. As stated earlier, most of these problems stem from ignorance, forgetfulness or excessive haste to get the job done. The end result may be an accident that could have been avoided.

3. **Bush Camps**

Temporary or seasonal camps, located in remote areas, and accessible only by helicopter, need a good helispot or
helipad. Ideally the landing site should be at least 100 m from the camp and if at all possible, in a sheltered spot. Having the site away from the camp means that minimum disturbance occurs when the helicopter lands or takes off. The landing site must be kept free of all loose materials (● 9.), and casual spectators watching the helicopters, should be discouraged. The latter is particularly important with people who are not trained in helicopter safety (for example, pick up crews). If a fuel dump is needed at the camp, it should be located on the far side of the landing site and provisions should be made to ensure that all possible precautions are taken during its use.

4. **Locating Landing Sites From the Air**

Often, either the pilot or the passenger will be selecting a landing site from the air. The points listed below should be considered.

1. Ultimately the pilot makes the final decision even though the passenger may be paying the bill. If the pilot is dissatisfied with the site, the passenger should accept his judgement. Similarly, if the passenger thinks that the pilot is risking
too much, then he should be open and honest with the pilot and suggest an alternative. No situation is worth risking the lives of two people and a helicopter.

2. Be aware of the size of the machine, its need for translational flight on take off, and its performance capabilities at maximum gross weights and altitude.

3. Look out for wind funnels that may cause stability problems for the pilot.

4. Be careful in the choice of ground landed on. Avoid soft ground and vegetated areas. It is not unknown for the rotor wash of a landing helicopter to flatten down the vegetation during landing, only to have it spring back up and strike the main or tail rotors when they were no longer displacing air. Also, the chances of a skid catching on the vegetation or some other snag should be allowed for.

5. Once a landing site has been selected and tried out, it should be maintained in line with any other helispot even if the use is only infrequent.
CHAPTER 7.  REFUELLING

Refuelling

Aviation fuel has a low flashpoint and is therefore readily ignited. In most situations the pilot will assume responsibility for refuelling the helicopter, but cases may arise when bystanders are asked to help. An understanding of the precautions needed will help to prevent needless accidents. ( 27,28.)

Fuel drums should be stored on their side or tilted, with the bung on the upper side, to prevent rain water from entering the drum. When the fuel is needed, the drum is tipped (if not already done) so that the bung is on the upper side. This allows any water or sediment in the drum to settle to the lower side. A filter is always used, and the fuel should be sampled prior to pumping into the helicopter to check for any impurities that may have escaped detection.

The fuelling process is as follows:

1. the helicopter is grounded;
2. the pump nozzle is grounded;
3. the fuel cap is removed and the fuel pumped in;
4. the fuel cap is replaced;
5. the pump grounding is disconnected;
6. the helicopter grounding is disconnected.
In several instances, pilots were observed refuelling the helicopter while the engine was still running. This practice, which is illegal (24:26,32 & 46,58) is termed "hot" refuelling. It is an extremely dangerous practice and at least one helicopter company in the Province enforces instant pilot dismissal if any violations are reported.

Although in the short run a few minutes are lost in shutting down the helicopter, safety is greatly increased, and strict adherance to the recommended procedures pays off in the long run.
CHAPTER 8.  THE LAYOUT OF RETARDANT PITS

In fire suppression operations, two types of retardant are commonly used; long term retardant, and short term retardant. Short term retardants rely on their water holding and cooling action to check the fire, while long term retardants contain additives which chemically alter combustion, inhibiting its spread. The following discussion concerns the layout of long term retardant pits, although some factors may be applicable to operations using short term retardant.

Retardant pits consist of two basic types, either a ground dipping pit, which is essentially a hole in the ground lined with heavy-gauge plastic, or a portable, canvas dipping tank. In either case the retardant is mixed away from the dipping tank or pit and is pumped in as needed. There are several factors to consider in the layout of retardant pits, some of which are listed below:

1. The pits need to be close to a water supply.
2. The pits must be accessible by road.
3. The pits must be away from other people, machinery, mobile radio bases, or other storage areas.
4. The ground pit or the dipping tank should be large enough and deep enough to take the largest bucket in use.
5. There should be enough clearance around the dipping pit to allow the helicopter to land if necessary.

6. There should be no obstacles in the exit path of the helicopter so that it can gain translational flight prior to gaining height.

7. The area surrounding both dipping pits and mixing pits should be free of loose materials.

8. The area surrounding dipping and mixing pits should be watered periodically to keep dust to a minimum.

During the field observations, the author noted both good and bad layouts. Figures 14 and 15 illustrate two examples. In the first (Figure 14) a large ground pit was used for dipping. This was about 6 m in diameter and was reported to be 2 m deep. The pit was carefully lined with plastic, and was fed by a delivery hose from the mixing tank. A dirt road separated the dipping pit from the mixing tank, which was about 8 m down the road. A flat-bed carrying the retardant was placed at the side of the road between the dipping and mixing areas, thus effectively isolating the mixing tank and its crew from the effects of the rotor wash. The delivery hoses crossing the road were between logs, so that wheeled traffic could use the road when helicopters were
Figure 14. Good layout of retardant area.
not dipping buckets. Periodically the dirt road was hosed down to prevent dust problems. All the helicopters had to fly in to the pit in a clockwise direction, and the bigger helicopter, a Bell 205, had priority over smaller helicopters such as Bell 206's. The only problem seen was that the Bell 206 often had difficulty gaining height once out of the pit; to gain sufficient translational lift, it had to fly down the road first.

Figure 15 shows a different layout. Originally, a ground pit had been constructed, but since it leaked continually, it had been abandoned in favour of a smaller canvas dipping tank. The problems here were many. Firstly, the mixing tank and the dipping tank were too close together, so that every time the helicopter came in and hovered over the dipping tank, the rotor wash hit not only the dipping crew but also the mixing crew. The rotor wash was seen to blow the powdered retardant around, temporarily blinding both crews. Neither crew was wearing goggles of any sort. When questioned on this, the crewmens' reply indicated that the rotor wash consistently blew up a fine spray of retardant which instantly fogged up the goggles, making it impossible to avoid the swinging bucket when it was lowered or raised from the tank. In all cases, the eyes of the workers appeared to be inflamed.

Secondly, the dipping tank was both too small and too shallow. Normally, the helicopter flies into the area,
Figure 15. Poor layout of retardant area.
hovers over the pit or tank, and gently settles down until the bucket is touching the surface of the retardant. Lowering a little more, the bucket tips over, and rapidly fills up. In this case, however, the pit was so small that three men were needed to guide the bucket into the tank, and once in the tank, the bucket had to be forcibly tipped over and filled. These three men were continually subjected to the force of the rotor wash and also were covered in retardant.

A better procedure would have been to repair the dipping pit. However, if this was not possible, it would have been better to have the pilot set the bucket down on the ground, and let one man fill it up from a high pressure hose. The time to complete this would have been no longer than that spent wrestling with the bucket in the tank.

Although every situation will vary, the layout of retardant pits clearly needs more consideration than has been seen in the past. With a little attention to the needs of everyone concerned in the operation, there is no reason why the retardant area should be any more hazardous to work in than other areas on the ground.
CHAPTER 9. ENVIRONMENTAL STRESSES

Generally, the stresses involved in helicopter operations are not widely appreciated by pilots or ground crew, although much work has been carried out in this area in military circles. In this chapter some of the environmental stresses will be discussed.

1. **Noise**

Very few people working in and around helicopters wear ear protection. This contrasts sharply with many airports where the ground personnel working in close proximity to aeroplanes wear ear protection most of the time. Possibly, people working around helicopters do not appreciate the magnitude of helicopter noise, or there may be some nuisance factor involved in carrying around a set of ear protectors all the time. For whatever reason, it should be clearly stated that the noise levels found in most helicopters are beyond the maximum acceptable levels of 90 dBA (24.). Prolonged exposure to this noise could result in impaired hearing.

The San Dimas Equipment Development Centre found in a preliminary survey (5.) of helicopter noise levels in a Bell 205, that the noise levels were:
73

<table>
<thead>
<tr>
<th>Location</th>
<th>Noise Level dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 m either side of the rotor mast</td>
<td>102</td>
</tr>
<tr>
<td>15 m in front of the rotor mast</td>
<td>89</td>
</tr>
<tr>
<td>15 m behind the rotor mast</td>
<td>98</td>
</tr>
<tr>
<td>inside the helicopter</td>
<td>93</td>
</tr>
</tbody>
</table>

Further measurements showed that there was also low frequency sound present in and around the helicopter, with readings ranging from 103-116 dBC.

Although the low frequency sound was not considered to be harmful, it effectively masked speech in the helicopter. The Centre concluded that the sound fields inside the helicopter during routine operations were loud enough to cause hearing damage if exposure was prolonged, but over short exposure times the damage would be marginal.

However, outside the helicopter the noise levels at distances of 15 m from the rotor mast, indicated that irreversible hearing damage was likely in some people after a two hour exposure. Exposure of eight to ten hours per day would cause permanent hearing damage. The Centre also concluded that the sound fields at distances of 61 m from the rotor mast, exceeded the long-term exposure level, during landing, hover, and take-off. Short exposures were not considered to be harmful, but exposures in excess of four hours per day would exceed the safe limits. Therefore, the Centre recommended
that personnel involved in helicopter operations for any length of time be issued with suitable hearing protection.

Skjenna (17:34) reported that sound levels in the 140 decibels region could cause nausea, vertigo, nystagmus,^1 incoordination and unconsciousness. Lesser sound levels may result in reduced consciousness, drowsiness, reduction in attention span, irritability and fatigue.

This analysis shows quite clearly the danger involved in continuous helicopter use without adequate hearing protection. More often than not, civilian pilots do not wear crash helmets, although it is mandatory in military pilots. The Centre did several tests on the efficiency of the pilot's helmet in reducing the noise levels, and found that the attenuation was only 9 dBA - less than a cheap pair of ear plugs. Thus, it is not only important to wear hearing protection, but also to wear the right protection.

Clearly the effects of noise should not be ignored, and an educational approach should be adopted to ensure that helicopter personnel do not suffer loss of hearing.

2. **Flicker**

Flicker is the phenomenon produced when a light source is interrupted by the revolving blades of the helicopter.

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1 Nystagmus. A spasmodic, lateral oscillatory movement of the eyes. (9:905)
Exposure to this phenomenon normally results in only mild discomfort and fatigue. However, some people react violently with convulsions and unconsciousness (17:35). The critical level of flicker varies between two to thirty flickers per second (f.p.s.). Skjenna suggested that six to eight f.p.s. resulted in reduced depth perception, nine to fifteen f.p.s. produced subjective effects, and twenty-five f.p.s. reduced concentration and might cause fatigue. Overall it is clear that flicker, while not a major problem, can contribute to pilot and passenger discomfort, ultimately detracting from the level of concentration.

3. **Vibration**

The vibrations found in helicopters are varied; the main vibration sources being the engine drive train and the rotor assemblies. The effects of vibration are also varied and range from discomfort and fatigue at twenty cycles per second to motion sickness at frequencies below one cycle per second. Visual acuity is adversely affected at about four cycles per second, and loss of binocular vision occurs at around eight cycles per second (17:37). Vibration has also been found to result in fatigue, decreased performance and back pains.
Skjenna (17:38) pointed out that the use of vibration reducing padding in helicopter seats is vital to pilot comfort, and also suggested that the seats be better designed so that they could be adjusted to suit the needs of the individual pilot.

4. **Other Factors**

Since the ventilation system in the helicopter is essential to maintaining clear, unimpaired vision, it is frequently used. By their design however, helicopters are prone to drawing in their own exhaust fumes, especially in the hover mode. Modern helicopters have allowed for this problem by relocating the air intakes, but even then, cockpit contamination will still occur in certain conditions.

In addition to cockpit contamination, it has been found that in some helicopters the ventilation systems are only just sufficient to maintain a comfortable working temperature. In a hover, the ventilation rates have been shown to be inadequate, leading to temporary discomfort for the occupants.

Finally, the effects of the downwash should not be ignored. It has already been mentioned in Section I that the downwash is sufficient to cause large heavy objects to be blown about. When a helicopter is hovering, in ground effect,
the magnitude of the resultant wind at ground level is inversely proportional to the height above ground of the thrust generator (17:41). Generally, the maximum winds are estimated to occur between 13 and 51 cm above the ground. The effects of working in the downwash have been studied. Results showed that energy expenditures of greater than 12.5 kilo-calories per minute were not uncommon when working in a wind of 93 km/h (17:42). This expenditure is equivalent to 'unduly heavy work'. Also, the effects of the downwash may cause severe chilling in certain conditions, greatly increasing the chances of hypothermia if exposure is prolonged.

A more usual effect of downwash is that of dust disturbance, which commonly causes eye irritation. This problem is not insignificant; flying dust and stones present a common hazard which everyone working near helicopters should be aware of.
CHAPTER 10. EMOTIONAL STRESSES

In Chapter 9, some of the environmental stresses inherent in helicopter operations were discussed. In addition to these stresses, there are also emotional stresses involved in certain types of work and the conditions that they represent. In routine helicopter operations the pilot is usually not under too much pressure, although a high level of concentration is always needed. However, on fire suppression operations there is much more pressure on the pilot (this also applies to emergency situations). This pressure is caused by the knowledge that if the fire is not brought under control as soon as possible, it will only grow larger and in the long run may cause many more problems.

During his field observations, the author talked to many pilots working on forest fires. It is clear from these discussions that the pilots should be given more consideration. The following discussion looks at some of the pressures involved in flying a helicopter in forest fire suppression operations.

Firstly, the helicopter is working in and around the fire, and the air is naturally very hot. This heat causes the cockpit to be warmer than usual, and also creates unpredictable air turbulence, which means that the pilot has to be more vigilant than usual. Secondly, the fire area is often
covered in pungent smoke, which causes varying degrees of discomfort and, in places, greatly reduces the visibility. Thirdly, the pilot is working under pressure to get the job done rapidly and effectively, and also to maintain accuracy when dropping water or retardant from a bucket. Yet, little allowance is made for fatigue and other environmental factors. (24,25.) Considering the above factors, it is clear, that with the levels of pressure commonly seen on fire operations, the degree of concentration needed is continually high.

In several cases, the author observed friction between the pilots and the fire boss on the ground. Often this was due to the fire boss having little or no knowledge of the operational requirements of helicopters. For example, one fire boss complained that the pilot flying one of the helicopters on that day had refused to drop a bucket of retardant on a hillside; on a previous day, a different pilot had done this without any problems. Talking to the pilot about this, the author was informed of a temperature inversion, which had put the site beyond the capabilities of the helicopter for the time being. The pilot had informed the fire boss of this problem, but the response suggested that the pilot was incapable. This type of situation is really inexcusable. Not only does it put a strain on all parties concerned, it also makes teamwork considerably harder to achieve. In the final analysis, teamwork is essential to carrying out a good operation.
In some cases pilots worked 14 to 15 hours per day. Some pilots worked long hours merely to boost their salary, while others clearly felt compelled to work long hours when everyone else was doing so. It should be understood that the pilot's job is more mentally demanding than almost any other job on the fire. For this reason, it is not unreasonable for the pilot to want a good lunch break, undisturbed and in a relaxed atmosphere, and also that the hours of work be shorter than some other categories of work.

At the end of the day the pilots should be able to eat and relax in a quiet, undisturbed place, with good quality food available at all times. In many cases the situation will make it impossible for some of these criteria to be met, but if they are at least appreciated then the pilots will have an easier time working. To a lesser extent, the same should apply to workers who are continually using helicopters. Such people as the bird dog officer, who supervises operations from the air, has much the same problems as the pilot, although the level of concentration needed is less since he is not having to fly the helicopter as well.

Overall, it is clear that the people controlling fires and the people responsible for the pilot's welfare should try to gain a better understanding of some of the problems
which the pilot is working with. Having understood these problems, steps should be taken to ensure that a greater appreciation is given to pilots working on forest fires.
SECTION II SUMMARY

In Section II, several operations have been discussed, and the safety precautions needed have been outlined. It is clear from the accident reports in Appendix 1, that many past accidents were the result of human error. Accidents due to mechanical failure have also contributed to the accident rates in the past, but these are beyond the scope of this report.

Accidents due to human error will never be entirely eliminated. It would appear that, in many cases, inadequate training is responsible for people making these mistakes. In the previous chapters, an effort has been made to describe how the individual operations should be carried out with a minimum of risk involved. There is a clear need for generally available training material in the form of slides, films, posters and leaflets.

The Workers' Compensation Board of British Columbia could make a worthwhile contribution to this area of work by providing some of these services. This would enable people working around helicopters in the future to better appreciate the inherent dangers of helicopters, and the reasons for taking safety precautions.
SECTION III.

AERIAL IGNITION SYSTEMS

Section III deals with problems inherent in the operation of aerial ignition systems. Several different techniques are described, with some discussion about the advantages and disadvantages of each one. The discussion in the preceding chapters is relevant to the operation of aerial ignition systems, particularly with respect to the operation of the helicopter and its requirements for safe flight.
INTRODUCTION -- AERIAL IGNITION SYSTEMS AND THEIR EVOLUTION

The use of aerial ignition systems for prescribed burning of forest slash and other vegetation forms (e.g. grass), first developed in Australia in the mid-1960's. The Australian system involved the use of a twin-engined aeroplane flying over the burn along a set flight path (3° & 12°). A person in the rear of the plane dropped incendiary devices, causing a line of fire to form on the ground.

This technique was modified in the early 1970's, for use in the Yukon Territory (Canada) as a means of starting a backfire in wildfire control. The system was basically the same, in that it utilised the same incendiary device, but in a modified container so that it could be discharged from the plane by a machine. Later on, machines were mounted in helicopters and allowed lines of fire to be laid down in the forest with considerable accuracy.

Parallel to the development of this means of aerial ignition, a different technique was developing in the area of slash burning. The traditional method of igniting logging slash is by means of a hand-held drip torch. This unit consists of a tank containing about 4-1/2 litres of fuel. The fuel flow and the fuel mixture can be varied to suit several types of slash. A group of men walk through the
slash lighting it as they move along. A variety of lighting patterns are used, depending on the conditions prevailing at the site. One of the problems incurred is that the lighting pattern is often erratic within the burn area, due to such factors as uneven distribution of fine fuels, varying moisture contents and uneven light up, giving rise to a non-uniform burn. Also, the length of the light-up period exposes the workers to more danger, and reduces the immediate efficiency of the fire.

The hazards involved in this operation are potentially high. The worker has to fight his way through the slash, making sure that it is ignited as he moves along. In heavy slash the chances of retreat are remote, and since the worker is committed to moving forward, if he tripped or fell in the slash the consequences could be lethal.

Few accidents have been recorded during this operation, but the following example illustrates very clearly how misuse of the system can result in a fatality.

On September 23, 1977, a 29-year-old man slipped and fell while walking over a steep slash area. In one hand he carried an open bucket of liquid fuel, in the other a lighted drip torch. 17 days later he died from third degree burns to 75% of his body. He left a wife and 9-month-old daughter. His job position was "Safety and Fire Protection Officer" (10:7).
This accident resulted from highly irregular practice, and it shows the potentially dangerous nature of taking short cuts in an operation which already involves potentially lethal hazards.

In the early 1970's, John Muraro of the Pacific Forest Research Centre (PFRC), in Victoria, B.C., evolved the idea of slinging a large-scale drip torch underneath a helicopter. Tests carried out in the Prince George district in 1972-73 indicated that the technique would allow faster and safer ignition of the slash, and further development was carried out (ill.). Since that time many variations have been designed, with the result that many different shapes and sizes of helicopter drip torch now exist in British Columbia.
CHAPTER 11. HELICOPTER DRIP TORCHES

The early design of the helicopter drip torch was very simple. It consisted of a 45-litre (10-gallon) drum mounted on a frame. A one-way valve allowed fuel (diesel) to flow out under gravity along a fuel line. The flow rate of the fuel was controlled by an adjustable valve located behind the one way valve. At the other end of the frame the fuel line fed into a pipe elbow. The fuel line went almost to the end of this elbow and doubled back on itself for about 16 cm. Inside the pipe elbow asbestos cloth was attached to the pipe walls to act as a wick. When the torch was in flight the fuel flowed out under gravity and dripped down the asbestos wick, thence to the ground. By having the pipe doubled back on itself, the fuel was preheated before it left the pipe, facilitating ignition. The fuel line also had a flashback loop built into it to prevent a vapour flashback to the drum.

The fuel drum and connections were of a quick release type, so that the drum could easily be disconnected and a new one installed. The whole unit was slung on the cargo hook beneath the helicopter either in a vertical position or a sloping position. The fuel supply was turned on and the fuel ignited manually on the ground. The helicopter then flew off to the fire site with the lighted torch and proceeded to ignite the slash.
The first problem that arose in the use of this device involved the lighting of the torch on the ground. If the slash was not next to the landing site the helicopter had to fly over other land first in order to reach the slash. Even if it flew at altitudes of 61 to 91 m, some fire would reach the ground and could cause unwanted spot fires. Also, if the fuel drum was not empty on return to the landing site, the helicopter had to land with a lighted torch, which was not considered a safe practice.

To overcome these problems, a remote controlled ignition system and an electric valve were installed in the fuel line. In theory, this would have enabled the pilot or another person in the helicopter to switch on the fuel flow, regulate it to the desired level, and ignite it once over the correct area. However, it was discovered the diesel fuel by itself is extremely difficult to ignite by remote control. To overcome this problem a mixture of fuels was then tried. By using a 60/40 mixture of diesel fuel and gasolene, the flashpoint of the mixture was lowered enough for remote ignition to be achieved. Once the fuel on the wick was ignited the torch functioned reasonably well. By stopping the flow of fuel, and allowing a few minutes for the wick fuel to burn up, the torch could be switched on and off at will.
Using a mixture of fuels meant that the gasolene (light fraction) would ignite easily and raise the temperature of the diesel (heavy fraction) so that it too ignited. Falling through the air, the lighter fraction burnt off, leaving the heavier fraction to hit the ground and ignite the slash. As a result of the lighter fraction of the fuel burning off before it hit the ground, more fuel was needed to achieve the same amount of ignition that diesel alone could achieve.

A difference in drip torch design now occurred. On the one hand the designers of the PFRC drip torch concentrated on finding a means of igniting pure diesel in the 45-litre torch, while the forest industry started to use a 205-litre (45-gallon) drum with a mixture of fuels. Industry made several modifications to the original design and today there are many designs in use. For the purposes of this report the original design by PFRC will be called the CFS design (Canadian Forestry Service), and the larger, later design will be called the Okanagan design.

The Okanagan Design

Plate 4 illustrates a typical example of the Okanagan drip torch design. Note the size of the torch relative to the person.
Plate 4. A typical example of the Okanagan drip torch design.

The basic layout of the Okanagan design consists of a 205-litre (45 gallon) drum mounted on a frame. The fuel is fed to the burning shroud by a fuel line, which has built into it, a remote controlled valve (operated by a solenoid) and a flash back loop. Some designs now in use have a fuel pump in the line to ensure a uniform fuel flow. A couple of designs have eliminated the flash back loop in the fuel line,
but, although the chances of flash back are remote, they should not be ignored. The flash back loop is a fundamental safety feature and should be present on all designs.

The methods by which the fuel is ignited also vary. One philosophy is that only helicopter spare parts should be used; since these are usually readily available at the helicopter depot. The other philosophy is to use standard auto parts, which are cheaper and just as easy to install, but may be slightly more difficult to obtain at the depot at short notice.

Whichever system is used, it consists basically of an igniter located in the burning shroud, and an exciter unit (similar to the coil in a car) mounted on the frame. The whole system is connected to the helicopter's power source (24 V.DC.) via a cable. Break-away connectors are used so that if the torch has to be jettisoned the power source is immediately disconnected. The complete drip torch when loaded weighs about 270 kg, and the fuel lasts about twenty minutes under average burning conditions.

The CFS Drip Torch Design

In its present form, the CFS drip torch consists of a 45-litre drum mounted on a small frame. Behind the drum is a bottle of propane gas. The fuel line, with a flashback
Plate 5. The CFS drip torch design.

loop, leads to the front of the frame, where it goes into a spiral tube. The propane leads via a steel pipe to the torch head, rated at 79 mega-joules. This is positioned just behind the fuel line coil. Originally this coil was made of copper, but the heat of the propane melted it; now, a steel coil of larger bore is used. Between the coil and the propane head is a standard automotive spark plug. A power booster transforms the helicopter's 24 volts DC to 24 kilo-volts. The spark plug is a long reach variety, with the gap being arbitrarily set, since the high voltage
eliminates the need for an accurate setting. The system works as follows: The diesel is turned on, then the propane, and finally the igniter button is pressed to ignite the propane. The flame of the propane heater carries down the spiral tube, heating the diesel as it flows. At the far end of the spiral tube the diesel is superheated and readily ignites. As it falls through the air in the form of a droplet, the outer surface is extinguished. When the droplet hits the ground, the inner core is still superheated and spontaneously bursts back into flame, thus igniting the slash.

In tests to date, the torch has proven itself to be highly efficient. It is considerably lighter than the Okanagan design, weighing only 91 kg when loaded, yet the fuel lasts for fifteen to twenty minutes under average burning conditions.

At the present time there is only one such model in British Columbia.

The Use of Jelled Fuels in Helicopter Drip Torches

The use of jelled gasolene for ignition purposes is not new. In military uses it is better known as napalm and has been extensively used in several wars. In more peaceful times napalm has been used for slash burning. The remote mass ignition technique utilises sealed canisters of napalm
simultaneously detonated with primacord. Once the firing pattern has been laid out, a large area can be ignited at one time.

Recently, a helicopter company in Oregon developed an aerial ignition system which uses napalm as the fuel. The system, developed by Western Helicopter Services Inc., is called the Western Heli-Torch. It is very similar to a helicopter drip torch, and consists of a simple frame on which a 136-litre drum (30 gallon) is mounted. A large bore (5 cm) fuel line leads to the other end of the frame. Near to the end of the fuel line is a sludge pump, and at the nozzle is an igniter. The whole unit weighs about 68 kg.

The fuel is normal gasolene to which Aluminium Octoate (trade name 'Alumagel') is added in a predetermined ratio. The Alumagel thickens the gasolene to a "jello" like consistency. In doing this it reduces vapour formation thus making the fuel safer to handle. In operation, the pump forces the jellied gasolene out of the nozzle in large blobs. The igniter sparks through the blob, igniting it. When the flaming blob hits the ground, it tends to splatter, spreading burning fuel over the slash.

So far, the problems which have come to light are that the fuel burns with a very sooty flame, and that the fuel does not last very long. A large block of slash ignited with Alumagel, and close to civilisation may have some environmental
Plate 6. The Heli-Torch.

Plate 7. Flying Too Slowly.
repercussions. At maximum fuel flow rates, 23 litres lasts for seventeen seconds, or 1.7 minutes for the whole drum (136 litres). Also the Alumagel is more expensive than either the drip torch or the AIDs (discussed in the next chapter), although there are currently few data to support this.

At the time of writing, there is only one model in British Columbia, and since Western Helicopters has a patent on the Heli-torch, development elsewhere may be slowed down. The system does have great potential, and if it can be refined to decrease its operating costs, it may well mark a new era in aerial ignition systems.

Discussion on Chapter 11

One of the main problems of using a drip torch, is that the helicopter has to fly low, and slowly. Under the optimum flight conditions, the helicopter is perilously close to the restrictions imposed by the 'Dead Man's Curve' (Chapter 2). Experience has shown that the optimum flame develops at an airspeed of 24 km/h. Flying at a slower speeds will cause the rotor wash to blow out the fire on the ground (Plate 7), or blow back the flame in the shroud. Flying too fast will cause the fuel to break up before it hits the ground.
Also, the greater airspeed creates turbulence at the burning shroud, atomising the fuel and creating a larger flame.

Ideally the torch should be flown about 3 m above the slash. Flying higher than this means that the fuel may not carry to the ground, while flying any lower than this increases the flying risks with no immediate gain in efficiency. This need to fly low means that all snags in the burn area must be felled since the pilot is: a) flying very close to the safe limits of the machine, with insufficient forward speed or altitude to make a safe emergency landing, and b) flying in smoke and generally poor visibility. In addition to these hazards, the air turbulence created by the updraughts, once the fire is burning well, makes it harder for the pilot to maintain a level course.

The CFS drip torch design can be flown at heights of up to 15 m above the ground, and faster than the Okanagan torch. The Heli-torch has overcome entirely the need to fly low and slowly since the helicopter can fly at heights of 15 to 90 m and at airs speeds of 80 to 95 km/h and achieve as good or better ignition than the other systems.

Coupled to all of these problems is the problem of depth of field. When the pilot is leaning out of the helicopter, it is often hard to judge exactly how far above the ground the torch is. This becomes harder as the height increases. The only advantage of flying low is that the rotor wash tends to fan the flames, greatly increasing their intensity.
The Fuels Used

As seen earlier, the fuel used ranges from diesel by itself to a mixture of diesel and gasolene. Some companies have started to use pure Jet B. fuel. This is the fuel used for turbine helicopters such as the Bell 206 Jet Ranger. In fact, Jet B and a mixture of gasolene and diesel are about equally hazardous, their respective flash-point ranges being very similar.(16.)

There are arguments in favour of each fuel type. Some argue that using Jet B eliminates the need to bring in diesel. This not only makes the logistics simpler, it also eliminates the risk that someone might inadvertently refuel a helicopter with diesel. Others argue that the gas/diesel mixture gives better ignition, and that the chances of using the wrong fuel in the helicopter are minimal. Whichever fuel is used, all refuelling should use procedures as strict or stricter than are used for the routine refuelling of helicopters. This means that the apparatus should be grounded. Also, the operation should be carried out away from the hook-up area because when the helicopter returns from the fire, the torch's burner will be hot and could conceivably ignite any spilt fuel in the area.
Slinging the Torch

There are several ways of slinging the drip torch beneath the helicopter. Figure 16 shows a typical arrangement. The main variation in slinging method is in the direction of the torch relative to the helicopter fuselage. In Figure 16 the torch flies at $90^\circ$ but in some instances torches have been flown in line with the fuselage, with the torch burner at the rear. There are also several methods of attaching the stabiliser bar to the skid, which serves to prevent the drip torch from spinning beneath the helicopter. With the torch at $90^\circ$, the pilot can remove the door of the helicopter, and during flight can look straight out onto the torch and monitor its position.

![Diagram of helicopter with drip torch slung](image)

Fig. 16. Slinging the helicopter drip torch.
CHAPTER 12. THE AERIAL IGNITION DEVICE (A.I.D.)

The first use of chemical ignition devices was during the mid-sixties in Australia (3 &12). Early experiments used pharmaceutical dispensing vials which were primed by hand and dropped from an aeroplane. The system was modified in the early seventies to allow mechanical dispensing of the incendiary device. The Pacific Forest Research Centre (PFRC) in Victoria, B.C., developed a spherical container 32 mm in diameter and made of high-impact polystyrene, allowing reliable mechanical dispensing to be achieved.

The device utilises an exothermic (heat generating) chemical reaction to ignite the material on which it lands. Each sphere contains approximately 3 grams of commercial grade, potassium permanganate (KMNO₄). Prior to dispensing, the sphere is injected with a 50/50 ethylene glycol and water solution. Approximately 30 seconds after injection, the reaction takes place, causing the sphere to burst into flame. The initial ignition temperature is 1,200°C which lasts for about 2 to 3 minutes. (8.) Thereafter the polystyrene burns at a lower temperature for about 10 minutes. Research is currently being carried out to find a coarser grained permanganate, which would give a greater delay time before ignition.
The latest model has a differently shaped AID hopper, but otherwise it is the same as its predecessor. The whole unit when operational weighs approximately 37 kg. The dispenser is designed to mount on the starboard rear door sill of a Bell 206. The door is removed for the duration of the operation. An auxiliary support has been designed to allow the dispenser to be mounted in a Hughes 500. The dispenser is held in position by means of a tie-down strap. This is attached to the outboard end of the dispenser, passes underneath the helicopter and back under the port door. It then ties onto the inboard end of the dispenser (Plate 8).

Plate 8. The AID dispenser mounted in a Bell 206.
One of the biggest objections that pilots have to using this system is that fear of having a fire develop inside the helicopter. If the dispenser jams it becomes apparent immediately because the dispenser stalls. Assuming that a sphere has just been injected, then the operator has approximately 30 seconds to rectify the situation. The operator turns off the AID feed control and then the motor. The operator then tries to clear the obstruction by rotating the manual assist. If this is to no avail, he then switches on the water supply from the extinguisher. This will extinguish the reaction before or as it occurs. The hopper is then removed, the chamber cleared of the obstruction and the system is ready to go again. All of the above takes very little time if the operator is proficient in the use of the system. At all times the operator is in contact with the pilot, by means of intercom, and keeps the pilot informed of the operation's progress and of any changes needed.

It is unlikely that an inboard fire would develop. However, if all else failed, the tie-down strap in the helicopter would be cut and the whole unit jettisoned. Similarly, if there was ever a flight emergency the dispenser unit could easily be jettisoned.

This system has several advantages over the drip torch. It eliminates the need to fly low, and slow. The helicopter can fly at heights of 60 to 90 m and at speeds
of up to 80 km/h depending on the ignition pattern desired. Obviously the faster the helicopter flies, the greater the distance between each spot fire. If speed is essential, the dispenser can be set up to discharge four spheres per second, but normally two per second is sufficient. The problem of having two fuels on the ground is removed, since only helicopter fuel is needed.

As with all systems, there are disadvantages. The A.I.D.s are a more expensive means of ignition than the drip torch. Each sphere costs about 10¢ and the dispenser costs about $3,500. In damp slash the ignition may not be as effective. In some cases it has been argued that the spheres will fall through the slash prior to ignition, thereby reducing their efficiency. Although this is possible, it does not appear to have been a problem on most of the operational tests carried out to date.

The A.I.D.s are definitely more efficient for use on backfiring applications in the control of wildfires. The system allows the line of fire to form on the ground even if there is a tree canopy present since the spheres carry down through the canopy. The drip torch cannot be used if a canopy is present since the lighted fuel sets fire to the canopy and not the ground fuels.
There have been some complaints from pilots that the system leaves a permanganate stain on the helicopter, which is difficult to remove. One company, which is now using the system on a large scale, has added an extension to the exit shute, and this has apparently solved the problem.

Some pilots do not like to fly the system, but when asked why they give no real reason. It seems likely that this system offers the pilot less of a challenge. Using the drip torch, the pilot (in some cases) may refuse to accept anyone else in the helicopter during light up. This means that the pilot is in total control of the helicopter and the fire and finds that he can exercise some judgement of his own on how the torch should be flown and how the ignition pattern should progress. When using the AIDs, he merely flies where the dispenser operator thinks is the best place for optimum ignition. He has much less chance to demonstrate his proficiency at lighting slash. Since the company having the slash burnt is paying for the operation, it seems reasonable that they should have control. Once again, as in the drip torch controversy, there is a clear need for greater understanding between the pilot and the person supervising the operation.
As with the drip torches, care should be taken to see that all pre-flight testing procedures of the AID dispenser are carried out away from the refuelling zone. Split fuel creates a potentially high hazard.

Overall this system is considerably safer than the drip torch, but its usefulness is restricted to certain types of slash and conditions. However, there is a place for it in the industry and its further development should be encouraged.
CHAPTER 13. CURRENT PROBLEMS IN THE USE OF AERIAL IGNITION SYSTEMS

Probably the most controversial point in all operations involving helicopters in aerial ignition systems, is whether or not the pilot should be accompanied by an experienced fire manager during the light up. Many pilots argue against this. When using the drip torch they argue that the helicopter is flying close to its limits already and that the extra weight of 91 kg, the approximate weight of one person, places the helicopter closer to these limits. Using the Okanagan design of torch, this argument may have some basis, but it is not valid when using the CFS torch, the A.I.D. s or the heli-torch, all of which are considerably lighter.

The difference in weights between the Okanagan design and the other systems is more than enough to allow an extra person to travel in the helicopter; in fact, the payload would still be less than with the Okanagan design by itself.

Many pilots like to think that they are more than capable of lighting up a fire. This is true, but there are very few pilots around who have the necessary burning experience to know how a fire should progress in all situations. Unfortunately, the pilots see the addition of a fire manager to the helicopter as a direct attack on their skills.
This controversy takes on a different form when the AIDs are being used. This system needs an operator to ensure that the dispenser runs smoothly. The problem now becomes who should be the operator. It is unlikely that the average fire manager will be skilled enough to operate the dispenser efficiently. So, assuming that the helicopter company, or the company having the slash burnt, supplies the operator, then should there also be a fire manager in the helicopter? In terms of the payload, two people and the AID dispenser still weigh less than the Okanagan drip torch, so the payload argument is not valid. However, having two people in the helicopter, both able to talk to the pilot over the intercom, would perhaps add to the pilot's problems. The ideal solution would be to have fire managers trained to operate the dispenser, but since this is unlikely, good rapport between the pilot and the other two people should be established. Once again the fire manager would be in charge of the fire, and would have the ability to direct the helicopter to wherever he deemed it was needed in order to obtain the best burn.

Overall, the problem of who should be in the helicopter becomes a matter for each pilot and each fire manager. If the pilot has good grounds for being alone then this should be considered, or, alternatively, if the fire manager thinks
he can manage quite well enough from the ground then that also would be acceptable. The most important factor is that everyone understands what each person's objectives are, and tries to cooperate so that the job is carried out efficiently, with no antagonism between the various parties.

Using any aerial ignition system the fire is quickly ignited and experience is needed to be able to predict the fire's behaviour and adjust the ignition pattern accordingly. Although the pilot is always in charge of the helicopter, an experienced fire manager may be needed in the helicopter to direct the light up.

Some pilots state that the area should be flown over prior to the light up with the pilot and fire manager discussing how the light up is to be carried out. The fire manager then stands at a vantage point on the ground and directs the light up by radio.

Another argument against having anyone else in the helicopter during light up is that the pilot has more than enough to do flying the helicopter, and ensuring that the speed and height of the helicopter is optimal. Having another person in the helicopter would distract the pilot, increasing the risks. To some extent this argument is valid. The pilot does have a great deal of responsibility to bear, ensuring that a successful light up is obtained. However, if another person were present, who was solely responsible for managing the fire, he would relieve the pilot of this responsibility,
leaving him free to concentrate on flying. The fire manager would direct the pilot where to fly and how the ignition should progress.

Transport Canada does not now have specific regulations dealing with the use of aerial ignition systems. However, all aerial ignition systems apparently contravene air regulation number 507 which states "No person shall create a hazard to persons or property on the ground by dropping anything from an aircraft in flight." (18:507) This is a general air regulation and does not apply solely to aerial ignition systems. In order for a helicopter company to be able to fly any aerial ignition system, they must apply to Transport Canada for a waiver to this regulation. If granted, the waiver is then written into the operations manual of the helicopter.

The AID dispensers currently in use all have waivers to air regulation 507. However, many of the drip torches in use may be being flown illegally. The original drip torches had an experimental waiver granted, so that the system could be tried. Since then, the waivers have not been renewed. The problem arises from the fact that drip torches are a sling load, hanging from the cargo hook.

In general, the helicopter companies are extremely reluctant to allow Transport Canada to formulate regulations on what can, or cannot be carried on the cargo hook. The fear is that such regulation would severely restrict helicopter sling loading operations, making it very difficult for the
companies to carry out even the simplest of operations without infringing these regulations.

It would be preferable if Transport Canada were to develop a set of guidelines concerning the construction and use of aerial ignition systems. Note that only guidelines are recommended; if these were properly put together, both the industry (helicopter and forestry), Transport Canada, and the WCB, would be better able to appreciate the situation.
CHAPTER 14. SUMMARY AND RECOMMENDATIONS FOR AERIAL IGNITION SYSTEMS

There can be little doubt that the advent of aerial ignition systems has radically changed prescribed burning. All the systems currently in use are effective in the right conditions and all have advantages and disadvantages. Of all the systems, the drip torch (Okanagan design) is the most hazardous since the helicopter is itself subjected to flying restrictions which are not encountered with the other systems.

All sides of the argument need very careful consideration before any guidelines or regulations are drawn up. The industries using the systems, that is the forest industry and the helicopter industry, should make a positive effort to sit down and decide on what they need from the systems. On the other side, Transport Canada should sit down and decide the criteria which they expect to be met, and whether or not regulation is really necessary. The following points may be considered in the light of the current developments in the design and use of aerial ignition systems.

Drip Torches -- Design

1. All torches should have a flashback loop built into the fuel line, to prevent vapour flashback.
2. The use of a preheater seems to overcome the need to fly low and slowly, and should be developed further. It also enables diesel to be used by itself.

3. Since the preheater allows diesel to be used by itself, a smaller drum could be used, allowing a second person to travel in the helicopter with the pilot during the light up.

4. The torch should incorporate remote controls, which are connected so that jettisoning the torch also cuts off the fuel and electricity supplies.

5. The use of fuel resistant stickers should be considered. These would outline the safe usage of the torch, and would be displayed on the fuel drums and torch frame.

Drip Torches -- Crew

1. The pilot should be familiar with the operation of a drip torch, even if the training consists of no more than flying the torch up and down disused gravel pits. The pilot should also be aware of the hazards involved in the operation.
2. Some experience with flying sling loads is a necessity for flying a drip torch. However, if a minimum amount of experience is stipulated, great care should be taken to ensure that this limit is reasonable and does not restrict the availability of pilots able to fly the drip torch.

3. One person, other than someone from the helicopter company should be in charge of the fire, its ignition, and "mop up".

4. There should be an experienced fire manager in the helicopter during the light up period. This person would have control of where the helicopter flies, but within the realms of possibility from the pilot's point of view.

5. All ground crew should be trained in the correct procedures involved in refuelling the torch and general safe practices around the helicopter.

6. Reliable radio communications with the pilot and the fire manager should be established from the ground. The pilot and the fire manager should have intercom capability. All radio chatter should be kept to a minimum level so that the pilot can concentrate on flying the torch safely and effectively.
Aerial Ignition Device

1. The pilot should be familiar with the system, and with exactly how the dispenser works. He should understand the procedures involved in dealing with jammed AIDs in the dispenser, so that he can appreciate what the operator is doing behind him.

2. The operator of the dispenser should be proficient in the use of the machine. He should be aware of all the procedures used in the safe operation of the dispenser, and should be experienced in fire behaviour.

3. If the AID dispenser operator is not also an experienced fire manager, then a second person, who is an experienced fire manager, should be present in the helicopter during the light up period. This person would have control of the operation and where the helicopter flies.

4. The AID dispenser should have clearly labelled instructions on its side indicating exactly how it is to be used. These instructions should include all the requirements needed for refuelling the system.
5. The AID system should be checked prior to flight and the recommendations listed in the manual that comes with the dispenser, should be closely followed.

The Heli-Torch

1. When the fuel has been mixed on the ground, care should be taken to ensure that no one is smoking, and that all the standard safety precautions are observed.

2. As with the drip torch, an experienced fire manager should accompany the pilot during the light up period.
SECTION IV.

CREW DEPLOYMENT TECHNIQUES

Section IV looks at two methods of deploying initial attack crews from a helicopter; helitack and helicopter rappelling. At the present time these are the only two methods being used in British Columbia, but other methods, such as smoke jumping (parachute attack), are in use elsewhere. Most of the discussion in Section IV has been extracted from another report by the same author, entitled Helicopter Rappelling: an appraisal of techniques currently used in fire fighting. (4.)
CHAPTER 15. THE HISTORY OF RAPPELLING

The technique of rappelling originated in mountaineering. The early climbers descended the rope by climbing down hand over hand, but as the climbs became steeper, a safer method was called for. The "Dulfer Sitz" evolved in Germany and consisted of passing the rope around the person's body in such a way that enough friction was developed to allow a person to slide slowly down the rope. Other methods evolved using a body wrap method and some are still widely used today. With more advanced technology, more sophisticated equipment was developed for rappelling down mountains and cliffs. Today there are many mechanical aids for use in rappelling, such as the figure-of-eight, karabiner brakes, brake bars, and in the use analysed here, the Sky Genie. All of these aids are descendeurs of one sort or another and utilize the friction of the rope on the descendeur to control descent.

A logical extension of the technique was to utilize a helicopter as the rope anchor, thus enabling a person to rappel down to any selected spot, without having to rely on finding a suitable anchor at that spot. This development was evolved by the armed forces and became commonly used for deploying troops into tight spots and for placing search and rescue teams at the sight of an accident. The potential for
eliminating access difficulties, and the logistical
back-up needed with conventional methods was clear, and
it was inevitable that the technique would be applied to
fire fighting.

The use of rappelling for fire fighting was first
examined in late 1971 by R. Henderson, of International
Forest Fire Systems (IFFS). In 1972 both IFFS and the
United States (U.S.) Forest Service in Region 6 started to
examine the potential of the technique for getting initial
attack crews (IA) out to a fire faster and more safely than
was possible with conventional methods.

After several years of testing, the system has now
been accepted as another means of deployment, for use in
forest fire fighting. The main difference between the
methods used in the U.S. and those in Canada lie in the
philosophy behind the use of the helicopter. In the U.S.,
only twin-engined helicopters are used, since the feeling
is that this will increase the safety margin should there
ever be an engine failure during the course of the rappel.
In Canada, a single-engined helicopter is used, the Bell 206
Jet Ranger; a discussion of its advantages and disadvantages
is given later (page 149). Fundamentally, however, the two
systems are identical.

The British Columbia Forest Service (BCFS) has tested
the concept of rappelling in fire fighting over the last few
years, and is now using a modified version of the original
IFFS system.
CHAPTER 16. WHY RAPPEL?

Many people who hear about the rappel programme initially have a very negative outlook on the operation. The whole concept of having people sliding down a rope attached to a hovering helicopter, appears at first sight to be extremely hazardous, considerably more so than the conventional method of "walking in" crew and equipment. Many people may seriously question the whole operation on the grounds of crew safety and cost.

This questioning is without doubt a good thing, since it gives the people responsible for the programme a chance to justify it on both counts. There can be no doubt that rappelling is potentially a dangerous operation, which should not be treated casually in any circumstances. In mountaineering, over 90% of all fatal accidents have been attributed to rappelling. However, the mountaineer is usually relying on an unknown anchor, and it is not uncommon for the strength of the anchor to be overestimated. People have been known to rappel from loose rocks and trees, with disastrous consequences. In helicopter rappelling, the anchor is tried, tested and certified prior to use. Assuming that the helicopter can continue to hover at the chosen location, the rope anchor is clearly considerably safer than in mountaineering.
What, then, is the problem? Procedures! Far too many people have been killed in mountaineering when rappelling, simply because they did not follow recommended procedures. People have rappelled past the end of the rope; they have forgotten to clip into the descendeur; and, they have neglected to wear gloves and have then lost control when their hands were burnt by friction with the rope. In mountaineering this is extremely difficult to prevent, especially when one considers that the rappel often comes after a long day's climbing, when the body is tired and the mind is least attentive.

In helicopter rappelling there are fewer people involved, each person is trained and disciplined in the correct procedures to be used, and they are usually rappelling when they are physically fresh and their mind is alert. Furthermore, the time which the helicopter spends in a hover while the operation is carried out is not long. For two men and the cargo to rappel to the ground from 61 m, takes a hover time of just under four minutes. Each rappeller spends about 15 to 20 seconds on the rope (30 seconds in the U.S.). This total hover time is not excessive; it takes about the same length of time for a helicopter to fill a retardent bucket, or a hook-up man to hook up a sling load underneath a hovering helicopter (allowing for manoeuvres to position the helicopter above the load). In the latter case, the operation is critical
since an engine shut down would result in the helicopter landing on the load. Viewed in this light, helicopter rappelling presents no more hazards than any of the other, more routine operations.

Canadian and American fire fighters have made over 60,000 helicopter rappels with only one minor accident. Obviously with the correct training and strict observance of the procedures drawn up, the operation is safe. This is not to say that it is a simple operation, or that anyone with nerve could go straight out and perform a helicopter rappel. The training involved is rigorous and essential to the continuation of a good safety record.

If then, the operation is a relatively safe one, despite its spectacular appearance to the layman, why should it not be used? The next objection is inevitably cost. Helicopters are expensive and their use requires careful evaluation if the maximum benefit is to be obtained.

The speed with which initial attack is carried out is the crucial factor in any fire suppression operation. Using conventional helitack methods, the helicopter flies the initial attack crew to a natural landing spot (helispot) as close as possible to the fire. The crew then walks to the fire and, if necessary, prepares a landing pad (helipad). Often they will be able to contain the fire, or retard its spread, until more men and supplies come in to help. One of
the major factors to consider is the time delay between detection and initial attack. Generally, the delay is longer with conventional means than with rappelling. Baron (2:24) stated that if the distance from the helipad to the fire in conventional helitack is greater than 463 m, then rappelling would be a more efficient means of initial attack.

Figure 17 illustrates this analysis. In the analysis it has been assumed that both the rappel helicopter and helitack helicopter have to land near the fire. The rappel helicopter lands to remove the port rear door, and to rig the rappel rope and cargo. The helitack helicopter lands to deplane the helitack crew and their equipment, so they can then walk to the fire site.

![Graph showing the relationship between distance and time from helispot to fire](image)

**Figure 17.** The relationship between distance and time from the Helispot to the fire.
The helitack helicopter needs to land as close as possible to the fire in order to minimize walking time. The rappel helicopter, however, can land some distance from the fire solely to rig the system; thus, the selection of a landing site close to the fire is far less critical. If the fire site is less than 48 km from the despatch base, then the rappel system is rigged at the base.

Figure 17 suggests that if point x is greater than 463 m, then it would be more efficient in time to use rappelling (2:24). By the time the helitack crew starts to walk (time zero) the rappel crew has landed, and has started to rig up the helicopter for rappelling. Approximately nine minutes later the rappel helicopter can take off for the fire, ready for the crew to rappel. This suggests that if the fire is less than nine minutes walking distance from the Helispot, then conventional methods should be used. However, the figures given by Henderson in his early evaluations of the system (7:9), show that differences in time are normally in terms of hours; hence, nine minutes either way is not too significant. Baron stated (2:24) that based on an all-terrain average (i.e., flat, moderate and steep terrain), rappelling was on the average 2.8 times faster than conventional helitack. Although Figure 17 makes no allowance for the difficulty of the terrain, it is probable that anything beyond flat, solid, and sparsely vegetated ground, will slow the helitack crew's walking speed to as little as 3 or 4 kilometres per hour.
Figure 18 illustrates the relationship between time to initial attack, and the costs of suppression. The time-cost relationship used has been assumed, although Henderson (6:7) suggested that on small fires the suppression costs will double for every 1/40 hectare increase in area, regardless of crew delivery costs.

Figure 18. Time-cost relationship between rappelling and helitack.
It is clear from Figure 18 that the suppression costs are lower if rappelling is used, since the initial attack time is drastically reduced.

This is not to say that a rappel crew is needed on every fire in the Province of British Columbia. For one thing, there are not enough qualified rappellers to allow this. Also, as with any fire operation, there will be times when there are not enough rappel helicopters available to attack all the fires at once. When a rappel helicopter goes out on a fire mission, it is committed. It is unlikely that the dispatcher can afford to wait for the return of the rappel helicopter before he sends out the next rappel crew. The initial attack time then would be minimized by use of conventional methods.

If there are few fires, or if the rappel crew decides that it can control or extinguish the fire with immediate attack, the rappel crew is best used by having it fight the fire before the helipad is built. However, if there are a great number of fires to be attacked, or if the rappel crew cannot control or extinguish the fire by itself, it may be better to use the rappellers solely for the purpose of building a helipad close to each fire. A conventional initial attack crew is then flown in to the helipad, and the rappel crew is taken to the next fire to repeat the operation.
The other costs to consider are those of training, equipment, and development. Appendix 2 gives a detailed breakdown of these costs. The total training and equipment costs for an eight-man rappel crew (amortisation period of five years) exceeds conventional helitack costs by approximately $703 per man per year. This cost figure is based on a five year amortisation period. The replacement period depends on the amount of use, presumably, a great deal of use is the result of a great deal of fire activity, and therefore the costs of replacement are easily offset by the savings in suppression costs.

Training costs will vary from year to year. Once the programme is set up, it seems reasonable to expect that some of the crew will come back the next season. There are bound to be new people to train, however, and in any case, the original crew has to continually train to keep their certification current. If a season is busy, with many fires, then the rappellers will have more than enough action. If there are few fires, then the rappel crew spends most of its time on standby, and since the locations of the bases in Northern B.C. are remote the crew morale may be low. In this case, some of the crew may not wish to return for another season, and new crew members have to be trained.
The following quotation is taken from a letter to the author, from a member of the rappel crew in RD 14. It is a typical example, illustrating the effectiveness of the rappel technique compared to conventional methods.

"Scoo Fire. 13.8.78. We built the helipad after one rappel and had the fire put out in short order. The closest natural helispot was five miles away and 457 m downhill of the fire. The rappel was invaluable to saving at least one day of time, and it eliminated the risks involved in having the men climb up through the thick bush and steep terrain carrying heavy gear."
CHAPTER 17. CREW SELECTION AND TRAINING

To maintain a good safety record it is essential that the people involved in rappelling are selected carefully. Hence, the crew selection procedure is strict.

The BCFS programme utilizes university students. In January 1979 approximately 200 students were interviewed at UBC for seven positions in the rappel programme. This selection procedure is carried out by Ranger J.P. Dunlop from Lower Post in RD 14, with an assistant from the district office in Prince Rupert. In order to qualify for a rappel position, each crewman must fulfill the following requirements (13:3.0):

1. Have a suitable application and employment history.
2. Be selected on the basis of a pre-screen interview.
3. Submit a satisfactory pre-employment certificate from a medical examiner.
4. Be in good physical shape and weigh not more than 84 kg.
5. Be able to achieve a rating of 45 or better on the "step test" after the initial training period.
6. Reach an acceptable standing on completion of training.
7. Must be able to function acceptably without glasses, if same are worn.
8. Demonstrate mental maturity.
9. Be entirely safety conscious.
10. Exhibit good co-ordination and ability to follow instructions.
11. Must have a good depth perception and the ability to distinguish basic colours.
12. Must have unimpaired hearing.

Finally, the crewman must continue to demonstrate rappel efficiency over the term of the programme.

The step test involves stepping onto and off of a block about 1/3 m high, in time to a metronome. At the end of 5 minutes the subject's pulse is read, and, together with the subject's weight, a ready reckoner is used to give a physical fitness rating. It seems doubtful, however, that the test can be given one-hundred-percent credibility. The author underwent the test in accordance with the parameters laid down, and scored a figure in the sixties, which was higher than any of the crewmen, who were clearly fitter. Also, one of the crewmen had an initial score in the forties, but at the end of the season, when he was considerably fitter, his score was more or less the same.
This was later found to be due to a minor heart complaint, which was previously unknown. Much research has been carried out in the U.S. on the validity of the step test as an indicator of physical fitness. Although results have proved it to be reliable, it should probably not be used as the sole criterion for judging fitness.

Training is divided into three phases: the classroom, the rappel training tower, and the rappel helicopter. In the classroom, the crewmen are taught the fundamentals of fire fighting, first aid, and the principles of rappelling. The crewmen are shown all the equipment used in the operation, and how each component works. They are introduced to all the procedures to be used in rappelling, including emergency procedures. This part of the training lasts about 10 hours (day 1). In the U.S. the classroom training is split up into units with an examination at the end of each unit, which has to be passed in order to proceed to the next unit (15). In the BCFS system, assessment of each crewman's performance is made at the end of the tower training phase.

The next training phase is the rappel training tower. Plate 9 below shows the rappel training tower at Lower Post in RD 14. The tower has three platforms: one at 2.5 m, one at 6 m, and one at 12 m. The training in this phase permits the crewmen to become accustomed to the procedures to be used. Each rappel from the tower is carried out as if it were from a helicopter, and includes
all the safety checks prior to each rappel. At the completion of this section, the crewmen are assessed, to ensure that the correct attitudes are developing. Crewmen who are considered unsatisfactory at this point are removed from the programme.

The final training phase is in the rappel helicopter. The crewmen are first given a refresher course in helicopter safety. They are then taken to a Bell 206 which is equipped for rappelling. The pilot and crew conduct mock rappels with
the helicopter on the ground, with each crewman in his assigned place. Finally, the crew rappel from a hovering helicopter, beginning with 9 to 12 metres above the ground, and progressing to 61 metres.

The whole course requires about 60 hours, over a period of 6 days. Upon satisfactory completion of all parts of the course, the crewman receives certification from the District Forester. The crewman is then qualified for operational rappels. Certification remains valid for 6 months, and is renewed only if the procedures specified in the operations manual have been followed, and if the rappeller has maintained a high standard of rappel proficiency.

In the operational rappel the helicopter carries one pilot, one spotter and two rappellers. (In the U.S. system there are more rappellers.) The spotter undergoes further training in addition to the basic training given to the rappellers. The spotter is responsible for the safety of the rappellers and for choosing the location on the ground onto which the rappellers will land. He co-ordinates the pilot and the operation. The spotter is expected to demonstrate leadership qualities and the ability to maintain discipline and crew respect. He is also expected to be very safety conscious and level-headed in all situations. To be certified as a spotter it is necessary to have at least one year's experience as either a rappeller or an apprentice spotter.
The rappel helicopter pilot must be completely qualified and current in all respects, and in accordance with the requirements of Transport Canada, Air Regulations. The rappel pilot must have not less than 1,000 hours total helicopter time and not less than 100 hours of sling time (i.e., flying with an external sling load) in a Bell 206 Jet Ranger. (13:5.0)

The pilot is trained in the procedures used in the rappel operation. In particular, he must be aware of the effects of the changes in the centre of gravity of the helicopter, due to the rappellers moving out of the helicopter and down the rope. The pilot has overall command of the helicopter and crew, but the spotter controls the rappellers and, through a microphone, keeps the pilot informed of the operation's progress. It is essential that the pilot be trained in the rappel operation to ensure the safety of the rappel crew. Pilots must realize that rappelling is a precise operation.

Throughout the fire season, the entire crew is expected to stay physically fit. In the BCFS programme the exercises are done at the discretion of the spotter, although it is stipulated that one hour of exercises will be carried out every morning. In the IFFS system the exercises are laid down with time requirements. In order, these are:
- 25 push-ups
- 7 pull-ups
- 45 sit-ups
- a run of 2.5 km

in less than 11 minutes. The exercises are to be done with no more than a three-minute rest between each set. This system is also used in the U.S. It forms the basis of the physical fitness test for smoke jumpers, and is considered to be a minimum level of fitness.
CHAPTER 18. THE EQUIPMENT INVOLVED IN RAPPELLING

The equipment used in rappelling is very specialized, and misuse may result in unpredictable failure. A detailed record should be kept of the usage that each component receives. Regular inspection should be carried out after each rappel, with a clear understanding that damaged equipment should be repaired or replaced immediately.

The rappel system consists of a rope attached to a specially designed anchor point on the helicopter. Attached to the rope is a friction device (descendeur) called the Sky Genie. The rappeller is clipped into a body harness. Between the harness and the Genie there is a quick release device known as a capewell. Plate 10 illustrates the basic components. Each component is described in detail below.

1. The rope anchor on the helicopter

The system used in the BCFS consists of a specially designed alloy plate which is bolted onto the side of the helicopter, just above the port (left) rear door (Plate 11). The bolts pass through the helicopter fuselage and are secured over a load-spreading plate. The bolts are wired to prevent loosening due to vibration. This design is
approved by the Ministry of Transport (M.O.T.) and is rated to a load of 585 kg. In fact, the load generated during a normal, smooth exit will rarely exceed 91 kg although in the event of a lock off (crewman stops descent while still on the rope) during the descent a momentary shock loading well in excess of this would be generated. This transient shock loading would affect the trim of the helicopter and the pilot should be aware of this.

Plate 10. Basic components of the rappel system.
The IFFS system is slightly different. It consists of an "A-Frame" mounted in the port rear doorway. The two legs of the frame attach to a hard points (structurally safe) on the helicopter, the top of the frame being held back by a third brace attached to a hard point above the door (Plate 12). In both systems the rope hangs down on the inside of the skid.

In the U.S. the rappel system uses a Bell 212 helicopter. This system allows two or four rappellers to descend at the same time, from either side of the helicopter. The ropes attach to a central anchor known as the "Iron Cross", located on the ceiling of the cabin quarters. The ropes then pass through a karabiner attached to a hard point just above, and inside the doorway. These karabiners hold the rope in position for rappelling, yet out of the way of the rappellers.

Plate 11. BCFS rope anchor.
Plate 12. IFFS A-Frame.

Figure 19 shows the three systems. In the Bell 212 the rope hangs down on the outside of the skid.
BCFS SYSTEM
Rope anchor on body above rear port door. Rope hangs down inside skid.

IFFS SYSTEM
"A-Frame" attached in rear port doorway. Rope hangs down inside skid.

USFS SYSTEM
Two ropes attached to ceiling anchor inside cabin. Rope hangs down over skid.

Figure 19. The three types of rope anchor.
2. **The rope used**

The ropes used are made of continuous filament, braided nylon, the maximum length currently being 76 m. At the ends of each rope are pre-formed loops secured by aluminium swedges. Stamped onto these swedges is the type of rope, the date of manufacture and the length. There may also be an identification number for use in the rappel log. Two rope sizes are used, the 9.5 mm which is rated at 1134 kg, and the 13 mm which is rated at 1814 kg. The BCFS is currently using only the 13 mm rope. Since these ropes are soft braided, they are flexible and handle well. However, the rope is prone to snagging and has poor resistance to abrasion. Being nylon, these ropes are also affected by ultra-violet light (sunlight) (21:6).

The rope is carefully stored when not in use, and is kept free of contamination. Twigs and needles snagged in the rope cause resin and pitch to accumulate in the rope fibres, causing friction spots to build up. This results in a jerky descent and also causes damage to the Sky Genie. The rope is coiled in a continuous system of half hitches, which allows the rope to uncoil under its own weight without tangling when it is dropped from the helicopter. This is called a "birdsnest" (Plate 13). After each rappel the rope is turned end-for-end to ensure uniform wear along the length of the rope, and also to prevent kinks building up
in the rope. If the rope is not changed round after each rappel the rappeller may experience a spiralling descent, due to the build-up of twist in the rope.

Each rope has a useful service life of about 200 rappels, after which it is retired or used for tower training. If a rope is wet, it is dried out before use, since a wet rope swells, increasing the friction and occasionally jamming in the Genie, making further descent extremely difficult. If an extremely fast descent is made, surface melting of the rope will occur, due to the heat build up as a result of the friction.

Plate 13. The rope coiled in a Birdsnest.
3. The Sky Genie

This is the friction device used for a controlled descent down the rope. It consists of an aluminium shaft which is enclosed by a separate aluminium casing. The number of wraps of rope around the shaft controls the rate of descent, two and a half wraps being ideal for a typical rappeller (84 kg). The rappeller can further control the rate of descent by applying tension to the rope below the Genie. To stop (lock off) during the descent, the rappeller slows down to halt by increasing tension on the rope, and then passes the rope up and over the Genie, thus locking the system off and preventing further descent. The casing prevents the rope from coming off the shaft, and it has a locking nut and a spring-loaded pin, which engages to prevent the casing from coming off (Plate 14).

The shaft has a load rating of 454 kg and is MOT approved. It is regularly inspected to ensure that the friction surface is free from contamination and blemishes which may damage the rope.

4. The harness

The harness used in rappelling is a modified parachute harness. It is constructed in the form of an
inverted "Y" and has adjustable shoulder and leg straps. When correctly adjusted, the rappeller is able to crouch or sit when wearing the harness. The two "D" rings at chest height provide the attachment point for the quick-release mechanism, the capewell. Since the harness is made of nylon, it is subject to deterioration when exposed to acids and sunlight(21:4-6). Regular inspection is essential to maintaining the harness in a safe condition.
5. **The capewell quick-release mechanism**

This device is found between the Sky Genie and the harness. Its function is to allow the rappeller to detach himself from the rappel rope in the event of an emergency. Plates 15, 16, 17 show the sequence of opening the capewell. Since it wears easily, it is only used in emergencies, and it is regularly inspected. In routine operations the whole assembly is detached from the rappel rope by unclipping the karabiner from the rope.

6. **The rappeller's kit**

The rappeller has a standard equipment kit which includes:

- leather gloves worn during the rappel to prevent rope burns;
- a helmet (the spotter's helmet has live microphone communication with the pilot);
- fire-resistant clothing;
- a good quality folding knife contained in a leather case and fastened onto the belt;
- a small first-aid kit;
Plates 15, 16, 17. The capewell and its use.
two nylon bags, one strapped to the right leg and the other to the waist. The leg bag contains a hard hat and work gloves. The waist bag has personal equipment and a portophone. When not in use, the complete rappel kit can be stored in the leg bag.

7. The cargo pack

The weight restrictions in the Bell 206 are such that the cargo pack is limited to 45 kg. Originally, the cargo pack was a long box shape (Plate 18) containing basic fire-fighting tools—a single side-band radio, a first-aid kit, emergency survival kit and some drinking water. Experience showed that this shape did not fly well and spun during flight. A new system has evolved in which a canvas bag is used. This seems to have overcome the problem of the cargo lanyards breaking due to spinning.

The cargo bag is attached to the helicopter cargo hook by a lanyard. This lanyard is approximately 2 m long. About 0.6 m from the end is a large metal ring. This ring goes onto the cargo hook underneath the helicopter. The long end of the lanyard extends from the hook into the cabin and it is tied onto the base of the seat-belt anchor with flagging tape (Figure 20).
Once the two rappellers have gone down the rope the spotter moves to the back of the helicopter and attaches this end of the lanyard onto a third Genie. The cargo is then jettisoned from the cargo hook, and slides off down the rope, guided by the rappellers on the ground.

In the U.S. operations the cargo is lowered differently. A separate line is attached to the cargo pack. This line passes through a "figure-of-eight" descendeur, which attached to the floor of the helicopter. The pack is then lowered to the ground by the spotter. The rate of descent is easily controlled by the spotter applying tension on the line as it passes through the descendeur. The rope
Plate 18. Helicopter and cargo pack; ready for action.

is colour-coded along its length so that the spotter can tell how much rope has been lowered to the ground, and he can then determine whether he has enough rope left to let another cargo down. If a helper is available in the helicopter, then several cargo packs are sent down, or a separate rope is used for each pack. Once all the cargo is on the ground, the descendeur is detached from the rope, which is then thrown to the ground by the spotter.
8. **The helicopters**

In Canada (British Columbia and the Yukon) a Bell 206 Jet Ranger is used for rappelling. The advantage of the Bell 206 is that it is very commonly used in Canada, and is therefore readily available for certification as a rappel craft. It is relatively fast, with a cruise speed of 193 km/h (120 MPH). Since the Bell 206 is relatively small, any helipads needed can be built quickly. The Jet Ranger carries:

- Pilot ............... 77 kg
- Spotter ............... 79 kg equipped
- Two rappellers .......... 159 kg equipped
- Cargo ............... 45 kg maximum
- Two hours' fuel supply ........ 145 kg

Subtotal: ............... 505 kg

Plus weight of empty helicopter ...... 817 kg

Total: ............... 1,322 kg

This allows a safety margin of 129 kg between the actual gross weight and the maximum allowable gross weight (13:8.33). Under certain circumstances, it may be difficult to maintain a suitable hovering position with this configuration. In this case, the cargo is deposited at a convenient location and, if necessary, the fuel load can be reduced. In any case,
the weight distribution is helped if the heavier of the rappellers exits first. In the Rappel Operations Manual (13:3.0), it is stated that the rappeller should not weigh more than 84 kg when fully clothed and equipped. The Bell 206 cannot safely maintain the hover mode with a lateral loading of more than 91 kg, since the load offsets the centre of gravity too much.

In the U.S. a twin-engined Bell 212 helicopter is used. This machine is capable of carrying 6 rappellers plus the pilot, the spotter, and all the necessary cargo. Its gross weight is 5080 kg; hence, there is a large margin of safety. The justification for using a twin-engined helicopter is that in the event of an "engine out", the helicopter still has one engine with which it can either make a landing, or fly out to a safer landing spot. Computer simulations of this one-engine-out situation, have shown that if the Bell 212 was in a stable hover at an elevation of 61 m above the ground, at an altitude of 2134 m above sea level, and with a payload of 4355 kg, the sink rates would be as follows:

<table>
<thead>
<tr>
<th>headwind (km/h)</th>
<th>sink rate (meters/minute)</th>
<th>time to touchdown (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>zero</td>
<td>146</td>
<td>25</td>
</tr>
<tr>
<td>18.5</td>
<td>55</td>
<td>67</td>
</tr>
<tr>
<td>37.0</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

Figures assume air temperature to be 24°C.
Further simulations of the likelihood of an engine-out suggested that the chance of this occurring during the actual hover operation was about one engine failure every 2,000 years (based on 10 helicopters operating with a total of 1,000 hours per season). The San Dimas Equipment Development Centre further analysed the operation and found that, based on the past experience with this type of engine, one could expect an engine shut-down during the hover mode once per 2,000,000 hours of operation. Since hovering comprises no more than one-tenth of the total operating time, this represents an engine failure rate of 0.005 per 100,000 hours in the hover mode (14).

Clearly, the Bell 212 is acceptably reliable. However, the costs of operating such a large machine on a rappelling programme are very high, and recently in the U.S. there has been some discussion of the relative costs and benefits of the rappel operation. Indeed, it seems clear that the costs of operating a Bell 212 may be too high and that the rappel programme may have to close.

In the Canadian systems, the event of an engine shut-down is more critical since the helicopter has no auxiliary power. Some helicopters are equipped with re-light kits which may alleviate the problem. However, in the event of an engine failure the Bell 206 would have to autorotate to the ground. Since it is in a hover with a maximum of 61 m
altitude, the elapsed time prior to touchdown is estimated to be 10-12 seconds. At set of emergency procedures is included in the BCFS Rappel Operations Manual to deal with the situations that might arise. So far, there have been no engine shut-downs in the hover mode in over 60,000 rappels.

In the opinion of the author it would be a retrograde step to allow only twin-engined helicopters to be used for rappelling. At the time of writing, the costs of operating a Bell 206 are considered high relative to the savings incurred on some fires regardless of attack method. The extra costs involved in using a Bell 212 helicopter instead of a Bell 206 would effectively rule out usage of the rappelling system for fire-fighting. The risk involved in rappelling from a single-engined helicopter is considered to be less than that involved in walking in to the fire through unknown terrain, carrying a heavy pack and being unable to keep a constant check on the location and size of the fire.
CHAPTER 19. THE PROCEDURES FOR RAPPELLING

Appendix 3 lists in detail the procedures taken during the rappel. Basically the rappel procedure is as follows:

1. The helicopter flies to the site of the fire.
2. If the fire is more than 48 km from the base, the helicopter lands before reaching the fire, and the spotter rigs the helicopter for rappelling.
3. The helicopter flies to the fire, a suitable rappel site is chosen.
4. The rope is dropped to the ground, the first rappeller is checked out and allowed to go down the rope.
5. The second rappeller is checked out and goes down the rope.
6. The cargo is attached to a Sky Genie and then sent down the rope.
7. The rope is detached from the anchor and dropped to the ground.
8. The helicopter flies off to the base, or to the landing spot previously used to prepare for rappelling.
9. Once the two rappellers are on the ground they pack up the rappel equipment, unpack the cargo drop and prepare to construct the helipad. Once this is done they start to control the fire. (In some cases, if the rappellers feel they can put the fire out with immediate action, they will do this before constructing the helipad).

10. If more support is needed, the helicopter can come in with reinforcements and more supplies for the fire fighters.

11. If there are many fires to fight, the helicopter comes back to the fire with a conventional initial attack crew. They then fight the fire while the rappel crew is flown out to attack another fire elsewhere, or to build another helipad at a different part of the fire.

12. Once the fire has been controlled or extinguished, the rappel crew returns to base and prepare for the next fire alert.

In rare cases, an emergency may arise either before, during, or after the rappel. The BCFS system has a well defined set of procedures that are to be followed in these cases (Appendix 4).
The procedures have been drawn up to cover virtually every conceivable situation that might arise. As in the rest of the operation, strict adherence to these procedures should ensure that the maximum effort is made to maintain a safe operation.
CHAPTER 20. LIMITATIONS AND RESTRICTIONS OF THE RAPPEL SYSTEM

The hover mode for a helicopter is one of its least safe phases, since it has no forward flight and is relying on relative wind and the rotation of the rotors for lift to maintain the hover. A headwind will help increase the amount of lift by increasing the relative wind, thus allowing less power to be used to maintain lift. However, gusts of wind cause the helicopter to drift sideways or rise and fall. The maximum allowable wind velocity for a satisfactory rappel is 32 km/h (20 MPH) with gusts of no more than 13 km/h (8 MPH). Not only do gusts of wind affect the helicopter's stability, but they could cause serious problems for the rappeller if the helicopter drifted sideways. If it is raining at the rappel site the rappel is aborted, due to the problem (already discussed) of rope swelling.

Restrictions on the rappel operation come from the Transport Canada Air Regulations and Aeronautics Act. Air Regulation number 511 states:

"Except as otherwise authorised by the minister, no person shall enter or attempt to enter any aircraft in flight or leave or attempt to leave any aircraft in flight, except for the purpose of making a parachute descent or give upon any aircraft in flight any gymnastic or other like exhibition."

The company operating the helicopter can apply to the regional air authority for a waiver to this regulation. This
waiver will then be written into the operations manual of the company and allows them to deplane people when the helicopter is hovering.

In accordance with Transport Canada regulations, people flying in the helicopter are under their jurisdiction. However, once the rappeller is suspended on the rope he comes under the authority of the Workers' Compensation Board of British Columbia (WCB).

Although there are specific WCB regulations governing helicopter rappelling, the employer and employees involved in this operation would come under Section 8 (Places of Employment - General Requirements). The regulations should be readily available at the rappel base, so that anyone interested could consult them.

There has been discussion of the merits of having two-way communication between the rappeller and the spotter. However, it is generally felt by the people rappelling that this is not necessary, partially because of a well-developed set of procedures which allow for all conceivable emergencies, and partially because of the very short duration of time spent on the rope. Once on the ground, the rappellers have radio communication (single side-band radio in cargo).
Summary

The system of helicopter rappelling presently used in British Columbia and the Yukon is well thought out, and presents less risk to the people involved than conventional methods of initial attack. In the U.S., the mandatory use of a Bell 212 helicopter for rappelling is causing problems. The high operating costs of this machine may lead to the elimination of rappelling from the fire fighters' repertory. In the opinion of the author the mandatory use of a twin-engined helicopter, solely on the basis of increased safety, is not justified.

The Bell 206 Jet Ranger has proven itself to be a highly reliable helicopter, with no incidents of engine failure during the rappel operation so far. This is not to say that an engine failure would not be highly critical. However, if the procedures that have been tried and tested over the past years are allowed, then an emergency can be handled effectively.

The greatest danger to the continuation of the rappelling programme does not lie in the apparent (but illusory) risk to trained people. Rather, it lies in a situation where poorly trained people who do not abide by all the procedures carry out operational rappelling with good intent, but with catastrophic results. So far this situation has not arisen. With correct training and use of prescribed procedures, it never will.
Helicopter rappelling is gaining more and more acceptance in several fields of work. The continued evaluation of safe procedures, and rigorous training of all those involved in the operation will ensure that this operation continues as an effective means of deploying people into remote locations.

The rappelling system, as a method of initial attack, now needs careful economic analysis to determine conditions where it would be most efficiently used, in combination with conventional methods.
CHAPTER 21. HELITACK

Helitack is a more conventional method of deploying initial attack crews. Since the safe operation of helicopters has already been discussed in Section 11, Safety In and Around the Helicopter, it will not be repeated here. The duration of initial attack time is a critical factor in the suppression of wildfires. Clearly the two systems are not equally suited to any one type of terrain, rappelling being suited to rugged, remote country, and helitack being ideally suited to flat open country, such as is commonly seen in the Chilcotin-Cariboo regions.

At the present time the main helitack base in British Columbia is at Riske Creek, near Williams Lake. It is here that the Forest Service has its Central Initial Fire Attack Crew (C.I.F.A.C.). This operation consists of six four-man crews, each crewman being trained in fire suppression techniques, and helicopter safety. An Alouette III helicopter is used, which carries a four-man crew, the pilot, and all the equipment needed to perform an initial attack.

In operation, the helicopter and crew fly out to the fire site, reconnoitre it from the air and then locate the closest available landing site. From here the helitack crew walks in to the fire site, carrying the equipment needed. In the Chilcotin area, helitack is an ideal method of crew deployment, since the terrain and vegetation restrictions are
not too severe, and therefore the crew is able to walk quickly and without undue effort. However, as seen in the discussion on helicopter rappelling, the difference in initial attack times between the two systems will increase rapidly once the terrain becomes steeper and the vegetation underfoot becomes denser. Another constraint on the present organisation of the helitack base is its location. At the present time, the furthest point in the fire district is approximately 190 km from the fire base; hence, if the helitack crew is called out to a fire in this area, the helitack helicopter is in use for several hours. The occurrence of a second fire elsewhere, means that a helicopter has to be called in from the Williams Lake airport, to transport three of the crewmen and the cargo (since the helicopter is likely to be a Bell 206 Jet Ranger, it can only carry three crewmen). If a third fire develops, it is possible (in fact such a situation was seen by the author) that there will be no further helicopters available in the immediate vicinity of the helitack base; hence, rather than waste time flying to the C.I.F.A.C. base the helicopter will land at the closest ranger station and use a pick-up crew. This means that 4 crews may be available to fight the fires, but due to lack of helicopters they are unable to be utilised.

It would seem to be more logical to have two helitack bases in the district, one at Tatla Lake for instance,
with three crews, and the others at Riske Creek. If both bases had a contract helicopter available, then the capability to attack fires would be increased since either helicopter would have to fly shorter distances and therefore the round trip time would be less.

Generally the crews at the C.I.F.A.C. base received a higher level of training than was seen elsewhere in suppression operations (except for the rappel crews). Because these crews have been specifically trained, and because they were using helicopters daily, the level of hazard awareness was high, and one would expect the accident rate to be very low. This situation will continue as long as strict adherence to safety procedures is always maintained, and the training programmes are available to continually reinforce these procedures.
SUMMARY ON THE SAFE USE OF HELICOPTERS

The original objectives of this study were defined as:

1. Determine the inherent hazards and potential for safety improvement in the use of helicopters for forest fire suppression and prescribed burning operations in British Columbia.

2. Develop recommendations which would contribute to greater safety in fire-related helicopter operations in British Columbia.

In the preceding chapters, several aspects of helicopter use have been discussed, hazards have been identified, and where possible safer procedures have been outlined. However, it should be noted that this report has not been able to cover all aspects of helicopter use in fire suppression operations, although much of the material presented in Section 11 will apply to most helicopter operations.

The main finding of this report is that many accidents caused by human error in the use of helicopters, are the result of poor or inadequate training. This lack of training was observed at several worker levels (from crewman to supervisor). The reasons for this inadequate training are not always clear; many organisations have training programmes,
some good and some poor, yet, accidents still occur, even with people who have been well trained.

Possible contributory factors are discussed. The main conclusion reached is that the people (other than pilots) who work with helicopters are not sufficiently aware of how helicopters operate. This lack of awareness leads people to take unknown risks; unknown until the accident happens. The problems of the rotor downwash drawing loose objects up into the rotors; helipads being built poorly and collapsing in use; and people not allowing enough room for translational flight, all provide excellent examples of this lack of awareness.

In some cases, the pilots are responsible for causing accidents, either by exceeding the safe operating limits of the helicopter in order to satisfy the customer's demands, or, by setting a poor example for other, less knowledgeable people to follow. A classic example of the latter, is when the pilot walks around the helicopter by ducking under the tail boom when the tail rotor is still spinning. The pilot is aware of the tail rotor hazard. However, people not trained in helicopter usage may follow the example set, yet be unaware of the tail rotor, which is often invisible when spinning.

Problems in the use of aerial ignition systems, are mainly in the design of the systems. There can be no doubt that aerial ignition systems represent a significant advance
in prescribed burning techniques, but some of the systems, particularly the Okanagan drip torch design, are potentially hazardous. Despite this, there have been no serious helicopter drip torch accidents so far. However, the advent of the Western Helicopter's Heli-torch, which uses jelled fuels, may radically change the whole design of aerial ignition systems. This development allows the helicopter to fly at safe altitudes and airspeeds, yet achieve an ignition pattern as good as, or better than that seen with more widely used (and older) systems. The helicopter rappelling operation reviewed in Northern British Columbia, provides an excellent example of how, well-trained crews, using well developed procedures, can function very efficiently and safely. The level of training and hazard awareness seen in this operation points the way to the safe use of helicopters.

Overall, the Workers' Compensation Board of British Columbia could make a worthwhile contribution to the safe use of helicopters in forestry, by providing training material and increasing people's awareness of the hazards inherent in helicopter operations. Such material should include posters outlining specific hazards, leaflets outlining specific procedures for avoiding these hazards, and training slides and films. All of the material should be readily available to the forest and helicopter industries throughout the Province. In addition, each ranger station would be able to use the posters on fire sites to educate casual crews.
The great diversity of operations involved in using helicopters makes it extremely hard to contemplate introducing any regulations that would be effective in reducing the accident rate. Furthermore, regulations do not appear to be the answer; rather than reduce the accident rate, they might well act in opposition, causing unnecessary frustration for the people to whom they apply, and eventually leading to more accidents. The alternative approach, suggested above, is to ensure that the level of job-related education is high, and that all categories of worker clearly understand why certain actions have to be taken. This latter course of action would undoubtedly be useful and acceptable to the industrial user of helicopters. In an area of work already well regulated, more regulations would probably do more harm than good.


FURTHER REFERENCES

The references listed below, although not specifically cited in the text of this report, are recommended as being essential background reading for anyone especially interested in helicopter safety, either in wildfire suppression, or in the use of helicopters in aerial ignition systems.


APPENDIX 1.

ACCIDENT REPORTS.
APPENDIX 1.

Appendix 1 is a collection of accident reports illustrating some of the hazards referred to in the text. Most of these accidents are not specific to any one field of work such as forestry or geology. Rather, they are accidents that are common to all helicopter usage and the lesson learnt from each accident applies to helicopter usage in all fields of work.

Listed below are the sources of information on helicopter accidents.

5. Accident Reports. Workers' Compensation Board of British Columbia.


Accident Report Format

Each accident report is laid out as follows:

Accident # (referred to in the text)

Type of helicopter. Crew injuries. Passenger injuries.

Damage: degree  (source #/helicopter reg'n #/
year of accident)

A brief description of the accident.

MORAL: a brief note as to what to avoid in future.
The following is an example:

14. Hughes 500C Crew...1 uninjured. Passenger...1 killed
Damage: substantial. (2/C-GUXB/77)
Main rotor struck deplaning passenger as he walked
uphill from the helicopter.
MORAL: Enter and exit on the downhill side and
in the pilot's field of view.

Transport Canada Air Regulations (Part 1. Section 101)
define an "Accident" as follows.

"Aircraft accident" means any occurrence associated
with the operation of an aircraft that takes place between the
time any person boards the aircraft with the intention of
flight and until such time as all persons have disembarked
in which:

(a) any person suffers death or serious injury as a
result of being in or upon the aircraft or by
direct contact with the aircraft or by anything
attached thereto: or

(b) the aircraft receives substantial damage or is
destroyed.
The definition of **substantial damage** is given in the Transport Canada Air Navigation Orders (VIII, No. 1) as:

"Substantial" damage means damage or structural failure that adversely affects the structural strength, performance or flight characteristics of an aircraft and that would normally require major repair or replacement of the affected component, except that engine failure, limited to an engine, bent fairings or cowlings, dented skin, small punctured holes in the skin or fabric, damage to propeller blades, damage to tyres, engine accessories, brakes or wingtips are not deemed to be substantial damage.

The following definitions are taken from source 6, Briefs of Accidents Involving Rotorcraft.

**Fatal Injury**

Any injury which results in death within 7 days of the accident.

**Serious Injury**

Any injury which:

1. requires hospitalisation for more than 48 hours commencing within 7 days from the date of injury;
2. results in a fracture of any bone (except simple fractures of fingers, toes, or nose);
3. involves lacerations which cause severe hemorrhages nerve, muscle or tendon damage;
4. involves injury to any internal organ, or any burns affecting more than 5% of the body surface.

This collection of accident reports is by no means representative of all helicopter accidents. The accidents listed here have been extracted solely to illustrate points in the text and to show that precautions are always necessary. It should also be borne in mind that for every accident documented, there were probably many "near miss" incidents, which were never reported. The reader is encouraged to refer to the sources of information listed above, to gain a more comprehensive insight into helicopter accidents.
The pilot landed to let off a passenger. The engine was in ground idle and the rotors spinning. The passenger unloaded his gear and to speed things up he threw an axe into the air intending it to land some distance away. The axe hit one of the rotors, shattering it.
MORAL: All items should be carefully unloaded, and never thrown.

Helicopter slinging equipment picked up a 431 kg drilling engine from its support stand. Engine hydraulic line snagged on the stand causing the aircraft to swing around as the pilot tried unsuccessfully to release the load. Main rotor struck the ground and the helicopter rolled onto its left side.
MORAL: Always check each sling load prior to lift off to ensure that all lines are clear and not snagged.
3. **Bell 206B.** Crew: 1 serious injury.

Damage: destroyed. (2/C-GHFC/77)

Slingload of plastic hose flew back into the tailrotor when the pilot increased airspeed after takeoff. Hose tangled in the tailrotor breaking off the tailboom, and aircraft crashed rolling on its side.

**MORAL:** Light sling loads need to be weighted down or put on a short lanyard, to prevent them from flying back into the tailrotor at speed.

4. **Bell 206B.** Crew: 1 uninjured.

Damage: substantial. (2/C-GSHH/77)

Lanyard hooked over skid as pilot was slinging fuel drums. Helicopter rolled over, crashed and burned.

**MORAL:** as in #2.

5. **Bell 204.** Crew: 1 minor.

Damage: substantial. (1/CF-AHL/75)

During a slinging operation, the pilot suspected an engine overspeed. He moved the machine laterally to clear the flight engineer who was under the helicopter attaching the sling, and landed on some empty oil barrels. The unstable landing platform caused him to lose control and the main rotors struck the ground.
MORAL: leave plenty of space when slinging in case the helicopter has to land suddenly.

Damage: substantial (1/CF-OAS/75)
The pilot did not maintain a vertical position over the sling load during the initial lift. The helicopter started moving in an erratic manner, dragging the load across the ground, until it struck trees at the edge of the clearing. A marshaller was not available to assist the pilot in his task.
MORAL: If at all possible, a marshaller should be present to help the pilot maintain position during slinging.

Damage: destroyed. (1/C-GHUV/75)
The helicopter was transporting a length of angle iron slung horizontally under the aircraft, which produced an unstable swinging load, and it struck the tail rotor. The load was not released and the helicopter entered a descending turn probably attempting to reach a roadway. Just prior to reaching the road the angle iron struck a tree, the helicopter landed on its side and burst into flame.
MORAL: as in #3.
   Passengers..2 serious, 7 minor.
   Damage: substantial. (2/CF-JTH/76)
   Upon take off a loose garbage can lid was blown up into the rotors. The helicopter fell to the ground, vibrating violently, where upon three main rotor blades broke off.
   MORAL: landing sites should be kept clear off all loose materials.

   Damage: slight. (7/not known/78)
   A helicopter coming into land on a roadside clearing, blew up a stray plastic lunch bag, which hit the main rotors with a loud bang. The plastic bag was welded onto the rotor blade. An engineer had to come out to the site and file off the bag before the helicopter could be flown again.
   MORAL: as in 8.

    Damage: slight. (4+5/CF-LDR/78)
    Helicopter landed with sling load. Crewman dis-connected the lanyard and threw it over his shoulder.
The lanyard struck the main rotor blade and dragged the lanyard through the crewman's hand. Crewman lost the middle and index fingers of his right hand. 
MORAL: Correct training and greater awareness could have prevented this accident.

Helicopter descended into trees as the pilot tried to turn back after beginning to settle during a climb over sloping terrain. High temperature and terrain slope were beyond the capability of the loaded helicopter.
MORAL: The prevailing conditions will alter the payload capability of the helicopter and should be allowed for.

The tail swung left during landing and struck a snow bank. The helicopter was near maximum gross weight and did not have sufficient power reserve to abort the landing attempt.
MORAL: Maximum payload can only be carried in ideal conditions.
The pilot was transporting four people plus equipment into a mountain site, instead of a sling load as originally planned. He circled the site once, then crossed the 45 m trees at the edge of the clearing, reduced forward speed and increased the rate of descent. Noticing that the turbine temperature was in the caution range the pilot took corrective action, further increasing his rate of descent. With insufficient power to overshoot or arrest the rate of descent, the helicopter selected its own landing site. The helicopter slid rearward and the tailrotor struck the ground.

MORAL: The pilot went out of his way to please the customer, rather than taking in two separate loads. The extra delay would have been worthwhile and safer.

Main rotor struck deplaning passenger as he walked uphill from the helicopter.

MORAL: Enter and exit on the downhill side and in the pilot's field of view.
Damage: substantial. (1/C-FAAF/76)
The helicopter struck a single unmarked hydro line 
during an attempted landing. The wire was difficult 
to see, however there were adequate visual clues to 
indicate the presence of the lines.
MORAL: Keep an open eye for unexpected hazards and 
if the pilot has not seen them bring them 
to his attention.

16. Bell 47. Crew..2 uninjured. 
Damage: substantial. (1/C-FRLV/76)
The right skid heel stuck in the soft ground. The 
helicopter translated sideways during lift-off, 
rolled over and crashed.
MORAL: On soft ground a helipad should be 
constructed to support the helicopter.

17. Bell 206B. Crew..1 uninjured. Passenger..2 uninjured. 
Damage: substantial. (2/C-GNNG/76)
After landing on soft ground, the helicopter tipped 
backwards as passengers deplaned. Pilot took 
corrective action but the tailboom struck the ground.
MORAL: Build a helipad, and have passengers 
exercise extreme care when exiting the 
helicopter.
Damage: substantial. (2/CF-CWN/76)
Pilot had landed on a log helipad and completed shutdown when a supporting log slipped. Helicopter slid backwards onto the tailboom.
MORAL: In helipad construction the logs should be spiked or notched into each other to prevent movement.

Damage: substantial. (2/C-FOAI/76)
The main rotor struck the ground after the right skid caught on a snag on lift off. Helicopter came to rest on its side.
MORAL: Helipads should be clear of all snags and obstructions.

Damage: substantial. (1/CF-LMA/75)
The helicopter was sitting on the pad preparing for take-off when the pad support failed and the helicopter slid off onto its side.
MORAL: Helipad construction needs to be strong enough to support the weight of the helicopter.

After landing on a sloping pad, the helicopter began to slip rearward. As the pilot applied forward cyclic to stop the motion, a lateral bounce developed and rapidly increased in intensity until the left main gear collapsed and the helicopter rolled over.

MORAL: Helipads should be built flat and level.

22. Bell 47. Crew...1 minor. Passenger...1 minor, 1 serious. Damage: substantial. (1/CF-VFH/75)

The landing pad on the side of the mountain had been designed for a Hughes 500. It was too close to a tree stump for this type of helicopter. The helicopter had to be balanced on three contact points and held in position with partial power. As the passenger stepped in, the helicopter moved forward and one skid snagged on a log. The helicopter rolled onto its side and caught fire.

MORAL: Always make allowance when building the helipad, for potential use by other helicopters.
While executing a pedal turn from the hover, the tail rotor struck a tree at the edge of the pad, shearing the tail rotor drive shaft.
MORAL: Always leave enough clearance around landing sites to give the pilot leeway for manouvre.

The main rotor blades struck a bulldozer when the pilot taxied too close. The pilot had flown 159 hours in the previous 30 days and probably suffered from fatigue.
MORAL: Pilot fatigue will contribute to accidents and employers should make allowances for it.

Several days of frustration due to poor communications left the spraying pilot short of temper. After he had topped up the spray tanks, he set down nearby to adjust a cushion behind his back. Impatiently he stood up to wrench the cushion up, and caught his knee on the collective. The helicopter flipped up and over, tossing the pilot out through the bubble.
MORAL: Employers should make allowances for fatigue and frustration factors.

Damage: substantial. (6/N9261F/76)
Passenger inadvertently blocked the right cyclic control with his foot. Main rotor blades contacted nearby apartment veranda.
MORAL: Passengers should receive full instructions from the pilot to ensure that they understand the Do's and Don'ts of helicopter flying.

27. Bell 206B. Crew..1 minor.
Damage: destroyed. (3/not known, see issue 2/78)
The helicopter was flown from its overnight parking pad to a separate pad about 900 m away. Weather was clear and cold. The pad had been cleared of snow leaving a thick matting of dead grass. The pilot landed and shut down the helicopter. A 205-litre drum was moved in, next to the craft, and the pump and filter with bonded hoses was set up. The pickup hose was placed into the drum and the pump laid on the ground. The helicopter fuel cap was removed.
and the refuelling nozzle inserted. As the nozzle touched the filter neck, a violent explosion occurred. Since the fuel tanks are behind the rear passenger seats, the full force of the explosion was directed into the cockpit area. The helicopter had not been grounded. During its short flight enough static had accumulated to cause an explosion. The grass acted as an insulator, and due to lack of grounding during setting up for refuel, an explosion occurred.

MORAL: Always ground the helicopter prior to refuelling operations. This accident also illustrates how much static can build up.

Model unknown. Injuries not known.

Damage: destroyed. (3/not known, see issue 4/77)

A helicopter with three people on board had just lifted off when the engine suddenly cut out. Touching down with some forward movement, it rolled onto its side after a skid dug in. Pilot and passengers exited after the main rotor had disintegrated. Engine stoppage was due to water in the fuel. Pilot had checked carburetor fuel drains on pre-flight check, but ice in the bowls prevented the water from showing up.
MORAL: Fuel drums should be stored and used in the correct manner taking due care to avoid water ingestion into the fuel.
APPENDIX 2.

COSTS OF EQUIPMENT AND TRAINING
APPENDIX 2

COSTS OF EQUIPMENT AND TRAINING
IN THE BCFS PROGRAMME, 1978

The figures quoted below have been extracted from the Witala report (23:5-10).

The cost of tower construction assumes that the rappellers build the tower in their spare time, hence labour costs are minimal.

All these figures are approximate.

<table>
<thead>
<tr>
<th>Fixed Costs</th>
<th>Annual Cost $/year</th>
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<tbody>
<tr>
<td>Tower construction @ $1,500 over 10 years</td>
<td>150</td>
</tr>
<tr>
<td>Cargo equipment @ $1,200 over 5 years</td>
<td>240</td>
</tr>
<tr>
<td>Complete rappel kit @ $2,704 over 5 years</td>
<td>540</td>
</tr>
<tr>
<td><strong>Sub-total:</strong></td>
<td><strong>930</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable Costs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Helicopter time for training 10 hrs @ $350/hour</td>
<td>3,500</td>
</tr>
<tr>
<td>Maintenance - tower</td>
<td>100</td>
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<tr>
<td>General maintenance</td>
<td>96</td>
</tr>
<tr>
<td>General replacement</td>
<td>800</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>200</td>
</tr>
<tr>
<td><strong>Sub-total:</strong></td>
<td><strong>4,696</strong></td>
</tr>
</tbody>
</table>

**TOTAL ANNUAL COST:** 5,626
This is the annual cost per year for an 8-man crew at 1978 prices. Therefore, the cost per man per year is $703.
APPENDIX 3.

THE PROCEDURES FOR RAPPELLING.
APPENDIX 3

THE PROCEDURES FOR RAPPELLING

The points listed below are taken from the BCFS "Rappel Operations Manual" (13:Appendix 1).

Pre-Flight

1. The pilot removes the rear door on the port side and prepares the helicopter for flight.
2. Spotter checks the rope anchor, attaches rope and stows two spare ropes.
3. Rappellers suit up and carry cargo to port side.
4. Spotter places cargo under helicopter and hooks it up with lanyard, attaching the free (long) end of the lanyard to the rear seat-belt anchor.
5. The rappellers, in turn, present their Sky Genies to the spotter, who inspects each Genie, places it on the rope, checks the rappeller's equipment and signals him into the helicopter.
6. The rappeller on the outside [port] seat is hooked into his Sky Genie and locked off. The rope coil is placed at his feet. Both rappellers fasten their seat belts.
7. The pilot swings the spotter's seat back into the forward position [ambulance configuration] and ensures the release handle on the post is wired securely.
8. The spotter hooks up his safety strap and double-checks the post release.
9. The pilot and spotter take their seats and check their live communications system.
10. Assuming all systems are prepared and O.K.; helicopter proceeds to the drop area.
Note: At distances of less than 48 km it is generally expedient to perform the above procedure at the attack base. At longer distances, it is suggested that the cargo be carried inside, and the door left on, until a convenient landing spot near to the fire is reached. Under ideal conditions, the ten steps above will require approximately seven (7) minutes.

Rappel Exit, Descent, and Landing Procedure

This procedure begins with the crewmen seated on opposite sides in the rear seat of the helicopter. The crewman on the exit side is hooked into his Sky Genie, which is positioned on the rappel rope. Both crewmen have seat belts fastened. The spotter has chosen the drop location, checked with the pilot, and turned in his seat to face the rappeller. Spotter now kneeling on seat, facing to rear of helicopter.

1. Spotter takes rope coil from crewman and drops it through the inside of the skid, to the ground.
2. Spotter checks to ensure rope is secure, and quickly re-checks rappeller's equipment, in a ten-point check. Check:-
   (1) chest snap,
   (2) & (3) "Y" harness snaps,
   (4) & (5) leg snaps,
   (6) quick release/capewell,
   (7) safety snap for Sky Genie attachment (karabiner on base of Genie),
3. Spotter maintains communication with pilot throughout operation.
4. Spotter points to crewman's seat belt, signalling rappeller to unfasten buckle and tuck belt to back of seat.
5. Spotter moves left hand horizontally from left to right, signalling rappeller to begin exit.
6. The spotter takes the rope in his right hand and moves it forward, to allow the rappeller an unencumbered exit.
7. The rappeller stands in a crouch and places his right hand on the back of his seat and his left hand on the back of the spotter's seat.
8. The rappeller pivots 90° on his left foot, ending with his back towards the outside of the helicopter.
9. The right leg is extended backward and the foot is placed on the helicopter skid.
10. The left leg is then extended out and downward, between the skid and the helicopter. It does not touch the skid. It is during this stage that the rappeller's weight will be placed on the rope.
11. The right foot is moved off the skid, inwards, and the rappeller assumes a suspended position, a short distance above the skid.
12. As weight is placed on the rope, the spotter releases his hold on the rope, allowing it to tighten smoothly.
13. The rappeller places his left hand on the rope, at a position near his left hip.
14. The right hand is used to take hold of the rope just below the Sky Génie.
15. Keeping tension on the rope, the rappeller unlocks the Sky Genie with the right hand by removing the loop with an arc motion.

16. As the loop is removed, pressure is applied downward on the rope with the left hand, to avoid beginning descent prematurely.

17. Using the left hand to control descent speed, by applying downward pressure on the rope, and using the right hand to guide the Sky Genie past the door frame of the helicopter, the descent is begun. As downward motion begins, the rappeller turns 45° to his right, (toward the rear of the helicopter) and guides himself past the bear paw.

18. Once clear of the helicopter skid, the rappeller places his right hand on the rope, approximately 10 inches above the left hand.

19. With hands in proper position, pressure is reduced on rope, and a smooth, quick descent is made.

20. As the rappeller nears the ground, he must slowly begin to increase downward pressure with the left hand to slow descent in preparation for landing. To facilitate smooth landing, the descent must begin to slow at least 20 feet above ground level.

21. Shortly before landing, the rappeller must choose his intended footing and spread his legs to avoid loosing balance on landing.

22. As the crewman's feet touch the ground he should bend both knees and assume a crouch position.

23. Immediately upon landing, the crewman grasps the rope near the top of the Sky Genie and pulls an extra six feet of rope through the Genie. This is to allow for any unexpected vertical movement of the helicopter while the crewman detaches from the rope. While pulling slack on the rope, the crewman must look up to check for signals from the spotter.
24. The crewman then releases his harness from the Sky Genie by releasing the safety snap, removes his Sky Genie from the rope, and exits the drop area.

25. Upon completion of step 22, the spotter moves the second Sky Genie into the helicopter, while still attached to the rope, and allows the second crewman to hook into it.

26. The spotter then signals the crewman to unfasten his seatbelt.

27. The crewman awaits the spotter's signal to move into the "exit seat" and then moves slowly into position.

28. Prior to exit, the spotter moves the Sky Genie up the rope, to ensure no slack exists which might cause a sudden movement during exit, and locks off the Sky Genie.

29. Steps 5 through 23 are repeated.

30. At this stage, two alternatives exist, which must be decided upon prior to commencement of the operation. They are as follows:
   (1) The spotter will remove the rope from the rope anchor and allow it to drop.
   (2) The spotter will commence cargo drop procedures.

Cargo Deployment Procedure

A. After completion of Personnel Deployment:

1. Beginning immediately after step 28 of the previous section, the spotter disconnects his communications line, and then re-connects it, after passing it around the outside of the door post.
2. The spotter then pushes the front door partly open, places his left foot on the helicopter skid, and pivots around the post and into the rear seat.

3. The spotter then hooks a Sky Genie to the rope, removes the free end of the cargo lanyard from the tie down, and snaps it to the Sky Genie.

4. Any slack in the cargo lanyard must be removed by sliding the Sky Genie up the rope.

5. The ground crewman moves into position, approximately $20^\circ$ fore and $20^\circ$ port, maintaining slight downward pressure on the rope.

6. When the ground crew is ready to control descent, the second crewman waves O.K. and the spotter returns the signal.

7. The spotter, holding the rope above the Sky Genie, pulls it outward to avoid having the Sky Genie hit the door frame on descent.

8. The spotter then tells the pilot "release cargo" to release the cargo from the hook.

9. The cargo will swing to the port side and begin to descend.

10. The ground crewman must be sure to allow a minimum of tension on the rope, so that the cargo will have both downward and outward motion simultaneously, to avoid sudden change in C. of G.

11. As the cargo nears the ground, the crewman should slow the descent to allow a gentle landing.

12. The crewman will wave an O.K. signal when the cargo is safely down, and the spotter will release the rope from the helicopter.
B. As a Separate Operation:

This is done when a cargo is being deployed at a time other than immediately after personnel deployment.

1. The spotter is seated in the back seat, on the port side, with communication line hooked up.

2. The free end of the cargo lanyard is hooked into a Sky Genie, which is positioned on the rope in the lock-off position.

3. When over the selected drop site, the spotter drops the rope coil.

4. Steps 4-12 of the previous method are repeated, with the following change: Upon completion of step 6, the spotter unlocks the Sky Genie.
APPENDIX 4.

EMERGENCY PROCEDURES.
APPENDIX 4

EMERGENCY PROCEDURES

In some circumstances, factors may arise which create an emergency situation which cannot be predicted. Following is a list of potential situations, and the procedures to be used for each one. Again, this is taken from the BCFS "Rappel Operations Manual" (13:8.2).

8.2 Emergency Procedures

A standard set of emergency procedures has been developed to ensure standard, safe action is taken in an emergency.

8.21 Communications Failure

In the event that the verbal communications system between spotter and pilot fails, the following procedure shall be implemented.

(i) if - the rope has not been dropped, the spotter will immediately turn to the pilot and signal to abort operation.

(ii) if - the rope has been dropped, the spotter will immediately detach crewman, release the rope and signal the pilot to abort.

(iii) if - a rappeller is making exit, or has not yet cleared the skid, the spotter will
immediately grasp the rappeller's harness and compel him to re-enter the helicopter. As soon as the rappeller is safely inside, he shall release his capewell, and the spotter will release the rope and signal the pilot to abort.

(iv) if a rappel is underway, and cannot be halted, the spotter shall wait for the rappeller to land safely, and will then release the rope and signal to abort.

8.22 Crewman Distress

In the event a crewman, while performing a rappel, is injured or unable to proceed, the following procedures shall be implemented.

(v) if the rope becomes lodged in the Sky Genie and descent is impeded, the rappeller shall immediately lock off, signal the spotter, pull six feet of rope from below and cut the rope at that point. The rappeller shall then knot the rope and apply firm downward pressure. The spotter shall keep the pilot informed, and when the rappeller has cut the rope, the spotter will direct the pilot to move slowly toward a safe landing zone.
(vi) if - the rappeller or rope drifts into a tree or other hazard, the rappeller shall immediately lock off and attempt to disentangle himself or the rope, and then proceed. The spotter shall keep the pilot informed, and if the rappeller does not succeed in freeing the rope, the procedure in Section (v) shall be used.

(vii) if - the crewman becomes entangled on components of the helicopter during exit, the spotter will immediately determine the problem, and if it cannot be easily rectified within 30 seconds, the spotter shall compel the rappeller to re-enter the helicopter and repeat the procedure outlined in Section (iii).

8.23 Helicopter Caution Lights

In the event a light on the enunciator panel signals the pilot of potential trouble, but not an immediately critical situation, the following shall take place.

(viii) the pilot shall immediately advise the spotter by saying, "I have a light."

(ix) if - the rappeller has not yet made exit, the spotter shall immediately detach crewman, release the rope and advise the pilot "all clear".
(x) if - the rappeller is in exit or has not yet cleared the skid, the spotter shall compel the rappeller back into the helicopter. Once safely inside, the rappeller shall release his capewell and the spotter will release the rope and advise the pilot "all clear". Should the rappeller be unable to detach from the rope for any reason, the spotter shall ensure the rappeller is safe, then cut the rope below him.

(xi) if - the rappeller is in descent, the spotter will repeat procedure in Section (iv) and advise the pilot "all clear".

8.24 **Power Loss**

In the event the pilot expects a loss or reduction in power, he must immediately advise the spotter "abort, power loss". The following procedure shall then be undertaken.

(xii) if - the rappeller has not yet made exit, or has landed safely, the spotter shall reply "all clear" and cut or release the rope.

(xiii) if - the rappeller is in exit or has not yet cleared the skid, the spotter shall compel him back into the helicopter, grasp the rope firmly, below the rappeller's genie, and cut it, as the rappeller reaches safety. He must
advise the pilot "all clear" as soon as the rope is cut.

(xiv) if - the rappeller is in descent, the spotter shall reply to the pilot "hold", and as soon as the rappeller has landed, cut the rope and advise "all clear".

8.25 Cargo Descent

Should the cargo fail to descend as planned or become entangled prior to landing, or another emergency occur during cargo deployment, the following procedure shall be undertaken.

In the event of communications failure, or caution light, the operation shall be aborted if the cargo has not yet been released from the helicopter cargo hook, and the rope shall be released. If the cargo is in descent, the operation will be completed as quickly as possible.

if - a power loss is experienced, the operation shall be aborted and the rope cut immediately, even if the cargo is in descent.
if - the cargo becomes tangled and cannot be easily freed, the rope shall be cut by the spotter.

In the event of a cautionary light, the pilot has approximately 45 minutes prior to landing before the situation becomes critical (1:22) (assuming that the instrument
lights function correctly). If one of the rappellers becomes injured on landing, the other rappeller signals to the spotter by crossing his arms above his head. The spotter then informs the nearest hospital and the ranger station of the emergency and a doctor is despatched. The second rappeller constructs a helipad by himself in preparation for the evacuation of the injured man. The emergency procedures in the U.S. are basically the same. The training manual covers all the points above (15).
APPENDIX 5.

THE METHODS USED TO CONDUCT THE STUDY.
1. **The Evolution of the Study**

Early in 1978 the Workers' Compensation Board of British Columbia (WCB) was approached, to find out where current problems existed in the safety aspects of the forestry operation. These preliminary discussions indicated that the use of helicopters in fire suppression operations and in aerial ignition systems, was one such aspect.

The objectives of the study were then defined as:

a) Determine inherent hazards and potential for safety improvement in the use of helicopters for forest fire suppression and prescribed burning in British Columbia.

b) Develop recommendations which would contribute to greater safety in fire-related helicopter operations in British Columbia.

Participation in helicopter operations was considered to be the best method of gaining an insight into the problems inherent in the operation. This not only allowed comments to be solicited from the people in the field, but it also allowed the whole operation to be analysed at first hand. However, the Province of British Columbia was obviously too large to form a reasonable sample area. It would have been
impossible, with the time and manpower available, to cover every wildfire and slashburn in the Province. Furthermore, because the location of wildfires could not be predicted, it was difficult to envisage a sampling plan that would yield sufficient information.

Similarly, the population of people involved in fire suppression operations was extremely difficult to accurately define initially, since to some extent, it depended on the number of fires in the season.

Originally, it had been planned to spend the summer in the Kamloops District (known to be a wildfire "hotspot") and evaluate fire suppression operations as the season progressed. However, this would have entailed waiting for a fire to occur - a tedious procedure and very wasteful of time.

The alternative plan was to spend one week in Northern British Columbia, undertaking a pilot study (in which interview techniques would be tried out, and some of the expected problems would be evaluated) so that the main study could be adapted where necessary. Thereafter, a modified technique (if needed) would be used to gather the main core of information considered necessary for the study.

It became clear, after this initial week's field work, that the best results would be gained by interviewing whoever was available at any one site. By visiting as many sites as possible along a predetermined route, the study would
build up a set of interviews with individuals representing different worker categories. This allowed several interpretations to be considered, which, along with the practical experience gained, would give a realistic insight into the problems involved in helicopter use.

2. The Interview Technique

At the outset it was clear that the method of soliciting information from people needed to be carefully thought out. Some problems were found in interviewing people during the pilot study, especially if they were asked directly about violations of safe practice. Very few people are able to admit, to an unknown interviewer, that they have made mistakes, no matter how large or small.

In order to build up a solid core of information, the use of the Critical Incident Technique (CIT) was considered. One approach to this method of study involves asking people to recall specific incidents which in their opinion increased or decreased the efficiency of an operation. In this study, the technique was to be used to elucidate good and bad practices around helicopters. Flanagan defined an incident as "any observable human activity that is sufficiently complete in itself to permit inferences and predictions to be made about the person performing the act. To be critical,

an incident must occur in a situation where the purpose or intent of the act seems fairly clear to the observer and where its consequences are sufficiently definite to leave little doubt concerning its effects".

A questionnaire was drawn up for each incident. Figure 17 gives details of this. The basic details of each incident were covered by a series of statements, each one having a box which could be checked if that detail applied. These statements covered most of the factors which were considered to be common to all incidents. Space was left for descriptive details such as a brief outline of the incident, and a diagram.

The aim of this system was to fill in a separate form for each incident discovered in the study period. At the end of this time it was proposed to draw up a set of categories indicating potential hazard areas. In conjunction with this, a set of crew categories was proposed, so that it would be fairly simple to see if different people recognised different hazards. It was hoped that the frequency with which any one incident occurred would give some indication of its chance of occurrence in the overall operation.

Once the critical incident forms were laid out and copies were available the pilot study was carried out.
SAFETY EVALUATION IN THE USE OF HELICOPTERS IN FIRE SUPPRESSION

Code Number: 

Experience (months) 

Position: 

Interview Date: day, month, year 

Briefly outline the incident and describe its role as a safety factor or as a hazard

Diagram.

Figure 21. The Questionnaire.
General

Type of helicopter.

Seating capacity of helicopter.

Dead weight lifting capacity of helicopter. (From specifications.)

Date of incident: day ___ month ___ year ___  Weekday (01-07) ___

Time of day ___ Air temperature (°C) ___ Wind speed (knots) ___

Altitude above sea level: metres ___ feet ___

Weather at the time of the incident:

Sunny. ___

1. No cloud.
2. Lightly overcast.
3. Heavily overcast.
4. Slight occasional showers.
5. Heavy occasional showers. Show the appropriate code in the box. If more than one, show the dominant code first.
6. Continuous fine rain.
7. Continuous heavy rain.
8. Snow.

Function of helicopter at the time of the incident:

1. Transport crew ___ helicopter crew ___ ground crew ___
   (Specify numbers where possible) supplies ___ for fire fighting ___
   *** for backup operations ___

2. Surveillance. (describe) ___

3. Fire fighting. (describe) ___

4. Fire lighting. (describe) ___
Operational conditions at the time of the incident.

<table>
<thead>
<tr>
<th>Helicopter on the ground.</th>
<th>Ground surface conditions at the landing site.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary.</td>
<td>1. Graded firm rock base.</td>
</tr>
<tr>
<td>Rotors turning.</td>
<td>2. Graded firm soil base.</td>
</tr>
<tr>
<td>Rotors stopped.</td>
<td>3. Combination of 1 &amp; 2.</td>
</tr>
<tr>
<td>Helicopter landing.</td>
<td>4. Uneven rock base (rock 10 cm).</td>
</tr>
<tr>
<td>Helicopter taking off.</td>
<td>5. Vegetated...weeds.</td>
</tr>
<tr>
<td>Topography at the landing site.</td>
<td>brush.</td>
</tr>
<tr>
<td>Flat open ground.</td>
<td>6. Concrete or tarmac.</td>
</tr>
<tr>
<td>Hummocky ground.</td>
<td>7. Water.</td>
</tr>
<tr>
<td>Side slopes.</td>
<td>8. Slippery due to: wet rock.</td>
</tr>
<tr>
<td>Visibility of crews and equipment.</td>
<td>wet vegetation...</td>
</tr>
<tr>
<td>Good. (All things readily seen).</td>
<td>9. Loose materials. (stones and twigs)</td>
</tr>
<tr>
<td>Medium. (Some visible).</td>
<td>10. Dusty. (Sand and other fines).</td>
</tr>
<tr>
<td>Poor. (Several blind areas)...</td>
<td>Landing site built as: heliport.</td>
</tr>
<tr>
<td>Lighting conditions.</td>
<td>helipad.</td>
</tr>
<tr>
<td>Good. (Broad daylight).</td>
<td>road.</td>
</tr>
<tr>
<td>Poor. Due to: dust.</td>
<td>turnout.</td>
</tr>
<tr>
<td>haze.</td>
<td>log landing.</td>
</tr>
<tr>
<td>time of day.</td>
<td></td>
</tr>
</tbody>
</table>

Number of people in the helicopter. (Describe job functions) ........................................ [ ]

Number of people on the ground. (Describe job functions) ........................................ [ ]
Operational conditions at the time of the incident.

<table>
<thead>
<tr>
<th>Helicopter in flight</th>
<th>Height above the ground:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>metres</td>
</tr>
<tr>
<td></td>
<td>feet</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of people in the helicopter</th>
<th>(Describe job function)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Number of people on the ground</th>
<th>(Describe job function)</th>
</tr>
</thead>
</table>

Briefly describe the nature of the operation.
During the course of this initial field work (designed as a testing stage for the interview techniques), it became clear that the CIT was not working too well. In most cases a good rapport was established early on in the interview and information was forthcoming, but generally with little concrete detail. Most of the people seemed to be wary of discussing helicopter accidents. When they did discuss them, they rarely gave enough detail to complete the forms. If pressed for detail, it had inevitably been forgotten. More often a brief outline of the incident was given, perhaps with some comments. It became clear that to keep the interview moving, that is to keep the respondent's interest, it would be necessary to take very abbreviated notes during the interview. Even though one of the opening statements by the author made it clear that any replies would be treated in confidence, many people continually asked not to be quoted on certain incidents. They became nervous if any details were written down, and in some cases it was necessary to write very little, and remember the information for later transcription.

After the first few interviews (by which time the author had gained some confidence) it became easier to discuss the various operations with people and it was discovered that much more information could be solicited by using open-ended questions in a loosely-formatted interview.
This open-ended questioning allowed the interview to start off with a specific question on one frame of reference, and by posing more and more detailed questions the respondent could be encouraged to give more detailed information on a more informal level. In most cases notes had to be made quickly, since the respondent would mention a point of interest and carry on to the next one straight away. If clarification was sought on any particular point, it became important to ask questions in such a manner that the respondent would oblige, without feeling under pressure.

Generally, the technique worked well, certainly better than trying to fill in a form for every incident. Also, using such a loosely structured method meant that subject areas could be switched and cross-referenced at will. Although this complicated the initial set of notes, later transcription was able to rectify this.

Copies of the incident forms were left with the rangers and helicopter companies, so that if any incidents occurred after the author had left, they could be documented and returned to the author. In the event, only one form came back, but it had been correctly used and did show that its basic layout enabled someone reporting an incident to do so with a minimum of mental effort. During the course of the summer, a loosely structured interview technique was used with success, although a few respondents proved extremely reticent.
Having evaluated wildfire suppression, the next stage of the study was to look at the use of helicopters in aerial ignition systems. At the start of the summer, the author had visited a demonstration slashburn, at which the drip torch and the AIDs were demonstrated. By following up on the contacts made at that time, a close evaluation of the several systems was made. Several other slashburns were visited in the Fall of 1978, but due to the high levels of precipitation, the fall proved to be a poor one for slash-burning. During the fall, the regulations concerning the use of helicopter drip torches became somewhat uncertain in the eyes of industry, and this provided an ideal opportunity to get involved with both sides (industry and the regulatory bodies) and learn more about the various methods of use.

3. The Literature Survey

In order to supplement the information obtained in the field interviews, a literature survey was carried out. Letters asking for specific and general references were sent to various helicopter user agencies in North America. The references and sources of information are listed in the Bibliography and Appendix 1. A survey of past accidents in the WCB accident files had been planned, but this proved to be impossible, since the computer retrieval system did not have a specific category for helicopter accidents.
With the literature available, the author was able to add to the observations already gained in the field, especially with respect to the performance problems inherent in helicopter flight. Wherever possible, specific accidents discussed in the field were located in the Transport Canada accident reports, to ensure that the field details were correct.

4. **Analysis and Use of the Information**

Once the interviews had been transcribed, and the literature had been analysed, a report was written, entitled: Helicopter Safety: The safe use of helicopters in fire suppression and prescribed burning.

Originally it had been planned to use the frequency of certain hazards as an indicator of their potential occurrence. However, at the end of the field work it was clear that most areas of helicopter usage needed some discussion, and so it was decided to write the report in 3 sections, each one of which covered a discrete part of helicopter operations.
Section I outlines how the helicopter flies and gives an insight into the routine problems faced by pilots. Section II discusses general helicopter safety, with specific chapters on some aspects of helicopter operations. This section discusses the problems involved in certain operations, and outlines some possible solutions. Section III deals with aerial ignition systems. Several systems are discussed and the problems and safety requirements of each one are outlined. Finally, in Section IV two methods of crew deployment are discussed, with the technique of helicopter rappelling being evaluated in depth.

Appendix 1 is a list of accidents, used to reinforce the points made in the text. Appendices 2, 3 and 4 refer to Section IV on helicopter rappelling. By laying out the report in this manner, all the points raised during the field work were incorporated into the report. However, it should be noted that not all the operations used in the suppression of wildfires, were evaluated. This was because of time constraints during the field work; it was impossible to evaluate such a diversity of operations in the time available.

Similarly it should be appreciated that the sampling methods used to obtain the data, contain many biases; not the least of which was the availability of people to interview. Because 1978 was a very busy fire season, it was impossible to formally interview as many people at the worker level as
might have been desirable, since they were usually out on the fire. This meant that more supervisory people were interviewed, due to their availability, and this may have biased some of the conclusions presented in this report. Similarly, the time of day at which the interview was conducted, the location, and the way in which the questions were asked, will all have built-in biases. No attempt has been made to quantify or define these biases, although their presence is acknowledged. Since this study was more an exploratory study to define some of the hazards, those biases are not seen to be seriously detrimental to the validity of the arguments presented. This report has defined some of the hazard areas, and made some attempt to propose solutions to these problems. Future work could now utilise the Critical Incident Technique more effectively. In particular, work could be carried out to evaluate training techniques, the role of the supervisory staff in enforcing safety procedures, and motivational factors at the worker level. Such an evaluation would allow more efficient training programmes to be developed, leading in the long run to better educated crews and lower accident rates.