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GENERAL AND COMPLETE DISARMAMENT

Napalm and other incendiary weapons and all aspects of their possible use

Report of the Secretary-General under General Assembly resolution 2852 (XXVI), paragraph 5

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INTRODUCTORY NOTE

This report has been prepared by a group of qualified governmental experts, appointed by their respective Governments in order to assist the Secretary-General in carrying out the task entrusted to him by General Assembly resolution 2852 (XXVI) concerning napalm and other incendiary weapons and all aspects of their possible use.

The members of the expert group were: Colonel Francis O. Aisida of Nigeria, Dr. Alexandru Denes of Romania, Dr. Jiri Franek of Czechoslovakia, Dr. Erik E. Moberg of Sweden, Professor Nikolai S. Nametkin of the Union of Soviet Socialist Republics, Major General Enrique Schroth of Peru, Brig. General (I.C.) Manuel Vásquez Barete of Mexico.

The group received valuable assistance from the World Health Organization and the International Committee of the Red Cross.

Dr. Rolf Björnerstedt, Deputy Director of the Disarmament Affairs Division, Department of Political and Security Council Affairs, served as Chairman of the group of experts. Mr. Henryk K. Pac, First Officer, Disarmament Affairs Division, acted as Secretary of the group. The group was also assisted by Dr. Frederick W. Ackroyd, M.D., Associate Professor of Surgery, Harvard Medical School, and Chief of Surgical Services, Mount Auburn Hospital, Cambridge, Mass., who acted in his private capacity as a special consultant to the Secretariat.

In transmitting this report to the General Assembly as requested in operative paragraph 5 of its resolution 2852 (XXVI), the Secretary-General wishes to express his appreciation and thanks to those Governments which appointed qualified governmental experts to serve on the group and the experts for their contributions in the preparation of the report.

LETTER OF TRANSMITTAL

22 September 1972

Dear Mr. Secretary-General,

I have the honour to submit herewith a unanimous report on napalm and other incendiary weapons, and all aspects of their possible use, which was prepared by a group of governmental consultant experts in pursuance of General Assembly resolution 2852 (XXVI).

The consultant experts appointed in accordance with the General Assembly resolution were the following: Colonel Francis O. Aisida, Nigerian Army, Nigeria; Dr. Alexandru Denes, Scientific Consultant, Centre for Chemical Research, Romania; Dr. Jiri Franek, Director of the Military Institute for Hygiene, Epidemiology and Microbiology, Czechoslovakia; Dr. Erik E. Moberg, Consultant to the Ministry for Foreign Affairs, Sweden; Professor Nikolai S. Nametkin, Corresponding Member of the Academy of Sciences of the USSR, Director of the Institute of Petrochemical Synthesis of the Academy of Sciences, Union of Soviet Socialist Republics; Major General Enrique Schroth, Peruvian Air Force, Peru; Brig. General (I.C.) Manuel Vásquez Barete, Scientific Adviser to the Ministry of Defence, Mexico.

The report was prepared during sessions held in New York from 15 to 19 May and from 24 July to 2 August, and finalized at meetings held in Geneva between 28 August and 1 September 1972.

The group of consultant experts wishes to acknowledge with appreciation the assistance it received from the World Health Organization, represented by Mr. J. P. Perry Robinson, and from the International Committee of the Red Cross, represented by Mr. Giorgio Malinverni.

The group of consultant experts also wishes to express its gratitude for the valuable assistance it received from members of the United Nations Secretariat and from Dr. Frederick W. Ackroyd, M.D., Associate Professor of Surgery, Harvard Medical School and Chief of Surgical Services, Mount Auburn Hospital, Cambridge, Mass., who acted in his private capacity as a special consultant to the Secretariat.

I have been requested by the group of consultant experts, as its Chairman, to submit its unanimous report to you on its behalf.

Yours sincerely,

(Signed) Rolf BJORNERSTEDT
Chairman
Group of Consultant Experts on Napalm
and Other Incendiary Weapons

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INTRODUCTION

1. In accordance with General Assembly resolution 2852 (XXVI), the Secretary-General was asked to prepare as soon as possible, with the help of qualified governmental consultant experts, a report on napalm and other incendiary weapons and all aspects of their possible use.

2. The objectives of this report are to provide information to peoples and governments on the effects of napalm and other incendiary weapons and all aspects of their possible use. It was envisaged that a report from the Secretary-General "on the question of napalm... could facilitate subsequent action by the United Nations with a view to curtailing or abolishing such uses of the weapons in question as might be established as inhumane" (A/8052, para.126).

3. The request for this report is not a single or isolated action. The International Conference on Human Rights, held under United Nations auspices in Teheran in 1968, adopted resolution XXIII entitled "human rights in armed conflicts", in which it suggested that the Secretary-General should study:

"(a) Steps which could be taken to secure the better application of existing humanitarian international conventions and rules in all armed conflicts;

"(b) The need for additional humanitarian international conventions or for possible revision of existing Conventions to ensure the better protection of civilians, prisoners and combatants in all armed conflicts and the prohibition and limitation of the use of certain methods and means of warfare." 1/

It was noted in this resolution that "the use of chemical and biological means of warfare, including napalm bombing, erode human rights and engender counter-brutality". In the same resolution, napalm bombing was mentioned as an example of the widespread violence and brutality of our times. It was also appropriate to mention in this context the two sessions of the Conference of Government Experts on the Reaffirmation and Development of International Humanitarian Law Applicable in Armed Conflicts organized by the International Committee of the Red Cross during 1971 and 1972. Among the experts consulted by the ICRC, a number declared themselves in favour of the prohibition of napalm.

4. Incendiary weapons may be defined, for the purposes of the present report, as weapons which depend for their effects on the action of incendiary agents. These in turn may be defined as substances which affect their targets primarily through the action of flame and/or heat derived from self-supporting and/or self-propagating exothermic chemical reactions; these reactions, for all practical purposes, are combustion reactions. Production of poisonous substances and certain other

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1/ Final Act of the International Conference on Human Rights (United Nations publication, Sales No.: E.68.XIV.2), p. 18.

side-effects may also bring significant harm to the target. These matters of definition, and of demarcation from other categories, are discussed further in paragraphs 11 to 36 below.

5. Chapter I provides a description of the principal types of incendiary agents and weapons that exist today. It draws attention to their great variety and notes that some are mainly intended to set fire to buildings, or destroy services and communications, over wide areas, while others are intended more as battlefield weapons. Of particular significance today are weapons based on napalm, some of which may be used against either category of target. "Napalm" was a term originally coined to designate a special type of thickening agent that was capable of converting gasoline into a particularly destructive type of incendiary agent. Nowadays the term has acquired a wider meaning and is used in this report to designate all types of incendiary agent made from gasoline, or from other light petroleum distillates, to which thickening agents have been added. Napalms are often exceptionally simple to make, requiring raw materials that are widely available in many parts of the world. In addition to such economic aspects, the chapter also notes certain trends in current incendiary development work.

6. Chapter II describes how fires take hold and propagate themselves through different types of surrounding. It describes the damage that may be suffered from incendiary weapons in built-up areas, in different types of material, and in the rural environment. The chapter is thus intended to provide a basis for the discussion in a later chapter of the military, social and economic consequences of incendiary-weapons employment. The chapter is also addressed to the question of providing protection against spreading fires, to the many factors which determine the spread of fires, and therefore also to the extent of the indiscriminateness of incendiary weapons.

7. Chapter III deals with the effects on the human body and on human populations of burning incendiaries, and of the fires caused by them. It is therefore primarily concerned with the medical consequences of incendiary warfare. The different ways in which incendiary agents, fire and heat can damage the human body are described in some detail. The description is not confined solely to the thermal injuries that may be sustained during incendiary warfare; it also includes an account of the poisonous and asphyxiating effects involved. Information is given of the lethality of the weapons, the pain which they cause, and the permanent disabilities or disfigurements which their victims are likely to suffer. A description is also given of the medical treatment that burn injuries, particularly napalm casualties, require, and this is discussed in relation to the likelihood of the necessary medical resources being available when and where they are needed. The chapter is therefore relevant to the question of the extent to which incendiaries may be considered particularly cruel means of warfare that may cause unnecessary suffering or superfluous injury.

8. Chapter IV describes the practice of incendiary warfare, past and present, the military rationale involved, and the social and economic consequences that may follow from it. One of the aims is to provide a perspective in which the relative importance of napalm and other incendiaries in present-day military

arsenals can be assessed. Of particular relevance here is the relationship between military necessity and the employment of incendiary weapons. Many of these weapons, often based on napalm, act over a wide area where their effects are indiscriminate. A related aspect, which is discussed on the basis of past experience, is the extent of the destruction which incendiary weapons can cause and the efficacy of protective countermeasures. The conclusions reached on these different matters are assessed in relation to the short-term and long-term impact that incendiary-weapons employment may have on the natural environment and on the fabric of human society.

9. The report closes with a section which draws together the principal features of incendiary weapons and incendiary warfare described in the four chapters. It assesses their broad implications for the future and presents a series of conclusions. The tenor of these is as follows: incendiary weapons are cruel weapons that cause great human suffering. There use is often indiscriminate as regards their targets. Because of this there is a need to consider measures for the clear-cut prohibition of incendiary weapons.

CHAPTER I

INCENDIARY AGENTS AND WEAPONS

10. This chapter describes the principal agents and weapons that exist today. Many different types of incendiary weapons have been developed. Some are intended as battlefield weapons; others, for use against population centres or fixed installations in the enemy rear; and others still for damaging crop-cultivations or other features of the rural environment. Some of the weapons are extremely simple, particularly those based on napalm, and they can be manufactured from raw materials that are readily available in many parts of the world. Research and development work continues, generating new incendiary weapons of increased destructiveness.

Definitions and scope

11. Napalm and other incendiary weapons are designed to inflict damage on an enemy, his possessions or his environment primarily through the action of heat and flame. Other categories of weapons may also have an incendiary action - as, for example, in the case of nuclear weapons - but this report is concerned only with those where incendiary effects are the ones primarily sought. 2/ Incendiary weapons may, however, have other damaging effects in addition to those of heat and flame. Some incendiary agents are poisons and some produce toxic or asphyxiating effects when they burn.

12. Incendiary weapon systems have three principal components: an incendiary agent; munitions for dispensing and igniting the incendiary agent in the target area; and a delivery system for conveying the munitions to the target. Munitions containing incendiary agents have been developed for most of the weapon delivery systems possessed by present-day armed services, including aircraft, artillery, naval ordnance, armoured fighting vehicles and the individual soldier. For each of these, more than one type of incendiary munitions is often available in order to provide for different military effects. As is described in the following section, and in the table contained in annex I, there is a wide range of different incendiary agents for use in these systems.

2/ High explosive weapons can sometimes initiate fires, but blast and fragmentation effects are their dominant ones. Nuclear weapons release large quantities of heat in the form of thermal radiation, this being responsible for a substantial proportion of their destructive effects: it has been estimated, for example, that the fire damage to buildings and other structures suffered when the atomic bomb was dropped in Hiroshima could have been produced by about 1,000 tons of incendiary bombs distributed over the city. Should the laser ever be developed into a weapon, its action might be an incendiary one. Smoke munitions, illuminating or signal flares or tracer bullets may sometimes have an appreciable incendiary effect.

Incendiary agents

13. An incendiary agent is a chemical, or a mixture of chemicals, which can be triggered into undergoing a chemical reaction that liberates a large and sustained quantity of heat. Almost invariably the reaction is that of combustion, namely reaction of a fuel with oxygen. The oxygen may either be incorporated in the incendiary agent in the form of an oxidizing agent, or it may be drawn from the air. For a composition to be an effective incendiary agent, it must have a high "heat of combustion", which is to say that it must release sufficient thermal energy to damage or ignite its target. Moreover, the rate at which this heat is liberated must neither be too fast nor too slow. If it is too slow, the target may be able to shed the heat which is forced upon it by the incendiary sufficiently fast for the net heat which it absorbs to remain below a damaging level. If the incendiary liberates its heat too fast, the heat may become dissipated before the target can absorb a damaging quantity. The generation of large flames by an incendiary, and also in most cases a high burning temperature, facilitate the transfer of heat between the incendiary and its target.

14. Targets vary in their vulnerability towards heat. The human body, for example, and inflammable materials such as weed or dry vegetation, are more vulnerable than structures composed predominantly of concrete or metal. For this and other reasons, a range of different incendiary agents has been developed. These can be grouped into four broad categories, namely metal incendiaries, pyrotechnic incendiaries, pyrophoric incendiaries and oil-based incendiaries. Napalm is an oil-based incendiary. Of the four categories, all but the pyrotechnic incendiaries derive their oxygen from the air. The pyrotechnic ones incorporate their own oxidizing agents.

15. An incendiary agent may also be classified either as an "intensive" type or as a "scatter" type. The intensive-type agents are designed for use against materials and buildings of low combustibility. For this purpose, it is necessary that they burn at a very high temperature and that their fire be held in a compact mass. Intensive-type agents include the metal and the pyrotechnic incendiaries. The scatter-type agents are designed for use against readily combustible targets, or as direct casualty agents against people. Such targets do not necessitate intense point-sources of fire and heat. They can be damaged if relatively small quantities of burning incendiary agent are scattered over their surfaces. Pyrophoric and oil-based incendiaries are scatter-type agents. Their destructiveness is greatest when they are sufficiently adhesive to cling to surfaces while burning, and adhesion-improving additives have been developed for them. Scatter-type agents are generally dispensed either by an explosive burst, as in aircraft bombs, or by ejection through a nozzle, as in flamethrowers. In both cases the viscosity, visco-elasticity and cohesiveness of the agent are important characteristics.

Metal incendiaries

16. Many metals react readily with oxygen of air, much heat being generated in the process. When heated to a high enough temperature, some react so violently that they incandesce and burst into flame. Because they are dense materials, they may therefore make efficient intensive-type incendiaries.

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17. Magnesium is the best known metal incendiary, and is the one that has been the most extensively used in war. 3/ It is not a particularly cheap material (its current price on the Western European market is about $700 per metric ton), but it is a widely used industrial commodity in many parts of the world. Certain other metals have a higher heat of combustion, but they are either too expensive or too difficult to ignite. As an incendiary agent, magnesium is usually employed as an alloy. One such alloy, known as Elektron, incorporates aluminium and small quantities of copper. A stick of Elektron or a similar alloy weighing a kilogramme or two constitutes a potent incendiary bomb, particularly when tipped with steel to aid penetration through the roofs of buildings. It may be ignited with a pyrotechnic composition, such as the thermite or thermates described in paragraphs 11 and 12. Magnesium takes fire when heated in air to about 600°C, and when burning it may attain a temperature approaching 2000°C, generating 6000 calories of heat per gramme consumed. It melts as it burns, and the molten burning metal may spread over an appreciable area.

18. Hot magnesium reacts with water to generate hydrogen gas, which itself may then ignite. This may complicate the problems of fire-fighting. Small magnesium bombs can, however, be extinguished relatively easily with sand or earth. In order to increase the difficulties of fire-fighting, explosive charges are sometimes included in the bomb casings. To the same end, the possibility has also been studied of alloying with the magnesium metals that generate a highly toxic smoke when they burn. 4/

Pyrotechnic incendiaries

19. Pyrotechnic incendiaries are ignitable mixtures comprising a fuel and an oxidizing agent. They therefore differ from the other categories of incendiary in that they incorporate their own source of oxygen and do not rely on the surrounding air for combustion. The admixture of an oxidizing agent with an inflammable material greatly modifies the burning characteristics of the latter, for example by accelerating its rate of combustion and increasing its temperature of burning. But at the same time the total heat output per unit weight is diminished, and only a few pyrotechnic compositions possess significant incendiary asset.

3/ Zirconium is another metal that has been studied as an incendiary agent. Its combustion properties are similar to those of magnesium, but it has the additional property of producing sparks when it strikes against hard surfaces. Uranium is also pyrophoric in air when finely divided. Depleted uranium is available in large quantities in some countries, and is finding an increasing number of military applications, for example in flechettes. Because projectiles of this type may pulverize when they strike a hard surface, the pyrophoric nature of the fragments may confer an incendiary effect.

4/ One such toxic incendiary alloy incorporates 20 per cent cadmium. The smoke that it generates is about twice as poisonous as hydrogen cyanide.

20. Thermite is the prime example of a pyrotechnic incendiary. It was the most widely used incendiary agent of the First World War, and continues in use to the present day. The fuel is aluminium metal, mixed as a powder with about three times its weight of the oxidizing agent, which is either magnetic iron oxide or ferric oxide. When ignited (via a starter-fire), this composition burns with great rapidity and violence, the burning temperature exceeding that of magnesium. Molten iron is released in the process; this may flow or be spattered over surrounding surfaces, thereby spreading the heat.

21. Despite its alarming appearance when ignited, thermite has a rather low heat of combustion, about 800 cal/g. Moreover it burns so rapidly that much of the heat generated may be wasted, and it does so without producing a flame. For these reasons, thermite is often modified by including other materials within its formulation. One such mixture is known as thermate. This comprises thermite mixed with an illuminating flare composition made from aluminium metal, barium nitrate and sulphur. A number of variants have been developed; some include carbonaceous materials in order to increase the total heat output. Thermates are easier to ignite than thermite and usually generate large flames. They are used today in incendiary hand grenades and in aircraft bomblets. The latter commonly employ magnesium-alloy casings.

Pyrophoric incendiaries

22. Pyrophoric incendiaries are materials which ignite spontaneously when exposed to air (which usually has to be slightly moist for this to happen). This property does away with the need for special igniters. Pyrophoric incendiaries are used on their own, or in conjunction with other incendiaries.

23. White phosphorus is a widely used pyrophoric incendiary. When exposed to air, it soon bursts into flame, generating oxides of phosphorus which, under the influence of atmospheric moisture, turn into a dense cloud of white smoke. For this reason, white phosphorus is used both as an incendiary agent and as an agent for creating smoke screens or smoke signals. Its heat of combustion (5800 cal/g) is comparable with that of magnesium but it burns rather slowly. Moreover, its combustion products tend to reduce the flammability of surfaces on which they become coated. For these reasons, white phosphorus is generally capable of setting fire only to the most readily combustible materials.

24. White phosphorus is a scatter-type incendiary. It is usually distributed over its target by an explosive burst. Particles of the agent adhere readily to surfaces while they burn. To increase its performance, white phosphorus is often used in formulations containing plasticizers and inflammable materials having a high burning temperature. The plasticizers ensure an even distribution of burning phosphorus particles of optimal size, whose adhesiveness they increase, and improve the ballistics of projectiles filled with the agent. A typical plasticized white phosphorus composition comprises finely divided white phosphorus particles suspended in a rubber-xylene gel.

25. Lumps of burning white phosphorus are difficult to extinguish with water, and even if water is effective, the lumps reignite when they are dry. Phosphorus fires are best controlled with sand or earth. One particular hazard of fighting phosphorus fires is the ease with which lumps of burning phosphorus stick to the boots and other clothing of fire-fighters. The large quantities of dense irritating smoke generated by the agent further impede the fire-fighting process.

26. White phosphorus is soluble in many organic liquids. Solutions in carbon disulphide have been employed as liquid pyrophoric incendiaries. These have been used as fillings for incendiary projectiles, bombs and hand-grenades. They have also been dispensed from aircraft spray-tanks: the sprayed liquid settles evenly over the surface of the target, and when the solvent has evaporated away, the phosphorus ignites spontaneously. Eutectic mixtures or chemical compounds of phosphorus and sulphur have also been employed as incendiary agents or as igniters for incendiary munitions.

27. White phosphorus is commonly used as an igniter for oil-based incendiaries charged into projectiles or bombs. When the munition detonates, an explosive charge drives fragments of phosphorus into the payload, which then ignites when the fragments come into contact with air. Other pyrophoric materials which have been used for this purpose include <u>sodium</u> metal, which ignites readily in contact with water.

28. Like magnesium, white phosphorus is not a particularly cheap material. Its current bulk price on the United States market is around $450 per metric ton. However, there is a substantial chemical industry that is based upon it, and its annual world production, which is growing, exceeds a million tons. About 15 countries in the world possess white phosphorus manufacturing facilities.

29. Of the many other pyrophoric materials that are known, <u>triethyl aluminium</u> is one which has recently come into use as an incendiary agent. This substance, which is a mobile, colourless liquid, has a particularly high heat of combustion (around 10,700 cal/g). It takes fire, sometimes with explosive violence, in contact with air or water. When used with a thickening agent, such as polyisobutylene, it can be scattered in burning gobbets that produce severe skin burns, ignite combustible materials and are extremely difficult to extinguish.

Napalm and other oil-based incendiaries

30. Hydrocarbons derived from petroleum oil are inflammable liquids that possess a high heat of combustion and produce a large flame. Because they are cheap (the current market price of crude oil is around $20 per metric ton) and widely available, they have long been studied and used as incendiary agents. Moreover, hydrocarbons burning in quantity frequently generate large amounts of carbon monoxide, which is a highly poisonous gas that may significantly add to the aggressive properties of oil-based incendiaries. Petroleum hydrocarbons have heats of combustion of around 10,000 cal/g, which is considerably greater than that of magnesium or white phosphorus. However, those of them which are sufficiently volatile to ignite easily, such as gasoline, burn so rapidly that when dispensed by

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a propellant charge, they are consumed in one large and relatively harmless flash. For this reason, gasoline is mixed with certain additives when used as an incendiary agent. These greatly increase its destructiveness. They modify its flow properties into a form more suited to weapons use, and make it sufficiently adhesive and cohesive to stick to surfaces in burning gobbets. They may also prolong its burning time and increase its burning temperature.

31. At the outset of the Second World War, the most common additive was rubber, which served primarily as a thickening agent to convert the hydrocarbon into a thick, sticky gel. As this became a critical raw material, much work was done on developing substitutes. Certain synthetic polymers soon came into wide employment, in particular acrylic resins such as IM (polyisobutyl methacrylate) and Perspex (polymethyl methacrylate). Later it was found that certain soaps had a number of advantages. Soaps are metal derivatives of the higher fatty acids, and there are a great many different ones. In 1942, it was discovered that an aluminium soap obtained from a mixture of coconut acid, naphthenic acid and oleic acid provided a particularly effective thickener. This substance came to be known as napalm. 5/ Nowadays the meaning of the word "napalm" has broadened to include not only the napalm soap, but also all types of thickened hydrocarbons used as incendiary agents. In the present report, "napalm" signifies any gelled-hydrocarbon incendiary.

32. The napalm soap described in the previous paragraph is a granular material that readily absorbs moisture from the air. It may be mixed with gasoline at room temperature to provide a gel that ranges in consistency from a thin syrup to a thick, almost solid jelly, according to the amount of soap used. A kilogramme of napalm soap is more than enough to convert 30 litres of gasoline into portable flamethrower fuel. Other types of napalm weapon make use of thicker formulations.

33. In many, but not all, respects, gasoline thickened with napalm soap proved superior as an incendiary agent to previous gasoline gels. It combines a prolonged burning time with great adhesiveness and certain other advantageous physical properties. Important among these are its stability as a gel, and its visco-elasticity. The gel does not liquefy when treated roughly, as does gasoline thickened with IM, but retains its cohesiveness during storage and when subjected to the mechanical forces of ejection through nozzles. Instead of issuing from the nozzle as a coarse spray of limited range, it can be projected for long distances as a continuous "rope" or "slug". What happens is that the more the gel is stressed, the lower does its viscosity become: although the gel may have the consistency of a thick grease before it is forced into the nozzle, it becomes as thin as lubricating oil while it is being ejected, and reverts to its original state when it emerges. For use in flamethrowers, this is a property of great importance, but in bombs that use a heavy explosive charge to disperse their contents it is considered a drawback; when stressed to this extent, the gel becomes so think that it breaks up into insufficiently large droplets. To be effective as a scatter-type incendiary agent, it is necessary that the napalm fragments be no smaller than 100 grammes or so.

5/ The word "napalm" is a contraction of "naphthenate" and "palmitate". It was at first supposed that it was the palmitic acid contained in the coconut acid which was responsible for the efficacy of napalm, rather than the lauric acid, as later transpired.

Large quantities of napalm soap or some other thickening agent may be needed to ensure this when the agent is to be distributed by explosive burst.

34. Elastomers such as IM continue to be used in thickened-gasoline compositions intended as incendiary-bomb fillings. An IM napalm of this type incorporates calcium cxide and stearic acid, which serve to modify the physical properties of the gel, and to generate an ash which provides a source of radiant heat. A related composition, intended primarily for use against poorly combustible materials, comprises IM napalm mixed with a pyrotechnic composition made up of magnesium oxide, heavy hydrocarbons such as asphalt, magnesium metal and an oxidizing agent such as sodium nitrate. Several different formulations of this type have been developed, some of them omitting the oxidizing agent or using different thickening agents. They are known as pyrogels. Although they generally release less heat than straight napalms, they burn at a higher temperature, well in excess of $1000^{\circ}C$.

35. The napalm soap of the Second World War continues in use today, but during the intervening years research and development programmes have produced - and continue to produce - still more effective thickeners. Some of them are also soaps, for example, the diacid aluminium soap of the iso-octanoic acids obtained by oxidizing a petroleum distillate. Some are synthetic polymers: polyurothanes, for example, have been found to give fast gelling times; copolymers of ethylene and propylene yield a gel that is stable over a wide range of temperatures; polyisobutylene gives a gel of prolonged burning time; and polybutadiene has been used as a thickener in a recent pyrogel composition. Materials such as Benthonite clay have also been used in making napalm. One of the most extensively employed of the new napalms comprises gasoline mixed with an equal quantity of benzene, the mixture being thickened with an equal quantity of a polystyrene. It has a greater adhesiveness than earlier napalms, greater storage stability, and lends itself better to large-scale production.

36. The aggressive properties of napalm can be modified by mixing in other materials. The pyrogels described in paragraph 34 are examples of "loaded" napalms of this type. Aluminium powder and polynuclear aromatic hydrocarbons may also be used to increase burning temperatures. An increased proportion of branch-chain hydrocarbons in the fuel has a similar effect. Pyrophoric substances have been used to ensure reignition of extinguished napalm fires. White phosphorus is one such material; it also serves to increase the casualty effect of the napalm. Sodium is another; it may not only increase the burning temperature of the napalm, but may also ensure that it remains alight in contact with water. Calcium silicide has also been used as a repeated-ignition additive. 6/

6/ Other additives that have been studied include such substances as the metal carbonyls. These were seen as a possible means, among other things, for increasing the toxic effects of napalm burning in a confined space. They are capable of generating both carbon monoxide and poisonous metallic aerosol.

Incendiary weapons

37. As noted earlier, a wide range of different incendiary weapons has been developed. In one category are those that are principally intended to set fire to buildings, or to destroy services and communications, in the enemy rear or in his towns and cities. In another category are those that are designed more as battlefield weapons, either for destroying vehicles, weapon emplacements or other matériel, or for use as direct casualty weapons against people. 7/ In some countries it is the practice to use the term "flame weapons" to denote the latter category. The distinction is not clear-cut, though, for both categories of weapon have on occasion been used against either category of target. None the less, a similar distinction is adopted in the following description: between incendiary weapons intended for use against population centres, on the one hand, and those for use against battlefield targets, on the other. The former comprise incendiary bombs designed for delivery by large fleets of bomber aircraft against urban areas. The latter comprise a range of air and ground weapons for use in tactical operations.

Incendiary weapons for use against population centres

38. Incendiary air attacks against population centres have been conducted in past wars by dispensing great quantities of bombs over the target area with the aim of initiating a large number of primary fires that subsequently spread of their own accord, developing into a conflagration. The combustibility of the buildings that comprise the target, and the ease with which falling weapons can penetrate them, determine the types of bomb that are used.

39. Against buildings that are made predominantly of brick, stone, concrete or metal, bombs containing intensive-type incendiary agents have chiefly been used. The bombs are made heavy and strong enough to penetrate through roofs. Small magnesium bombs of the kind described in paragraph 18, and thermate bombs (with the agent loaded either into magnesium-alloy or steel casings) weighing a few kilogrammes, have been the most widely used. Also, but less extensively, used have been massive bombs containing scatter-type agents such as napalm or pyrogel. These may weigh 50-250 kilogrammes or more, and are capable of penetrating not only roofs but several floor levels as well. Upon detonation, they spatter their contents over the inflammable interiors of the buildings.

40. The small magnesium or thermate weapons have generally been dropped in clusters containing a hundred or more. The cluster units open above the target to distribute their bomblets over the target area. Many small fires may then be created in close proximity to one another, and this has proved particularly favourable to the development of a conflagration. It is for this reason that, even though a massive bomb dispensing scatter-type agent may have a greater probability of setting fire to

7/ Napalm weapons are used against both these types of battlefield target. To adopt one current system of military terminology, they are both "antipersonnel weapons" and "antimatériel weapons", and are accordingly sometimes referred to as "anti-PAM" weapons.

a building, bombloads of them are less likely to start a conflagration than the same number of bombloads of clustered magnesium or thermate bomblets.

41. Against readily inflammable targets, scatter-type incendiary agents are used. A peculiarly destructive weapon is the small bomblet that is designed to eject a kilogramme or two of napalm through its tail section upon impact. Like the magnesium weapons described above, such bomblets are delivered in clusters. A typical 3-kg. base-ejection bomblet of this type uses about 0.2 kg. of white phosphorus to ignite its 1-kg. napalm payload.

42. White phosphorus bombs weighing 20 to 50 kilogrammes have also been used extensively against population centres. They are generally less effective in starting conflagrations, but they are considered to have a particularly demoralizing effect upon the inhabitants of their targets. A related type of bomb weighs around 100 kilogrammes and has a payload comprising about 20 kg. of rubber-gasoline gel and 10 kg. of a phosphorus-sulphur mixture.

43. Incendiary bombloads dropped on urban areas have generally contained a proportion of high explosive weapons. These are intended to shatter windows or break down walls, thereby increasing the inflammability of the target area. They are also intended to rupture water-mains and destroy other public utilities, thereby impeding fire-fighting activities. To the same end, incendiary bombs are often fitted with delayed-action explosive charges.

Air weapons for use against battlefield targets

44. Tactical aircraft supporting ground operations have frequently used incendiary weapons. Against fixed installations, they may employ the same weapons as those described above. Another weapon, the "fire-bomb", has been extensively used by ground-support aircraft against installations and vehicles. It is also a potent casualty weapon when used against populated area targets. It comprises a large, thin-walled container, shaped like an auxiliary fuel tank, charged with napalm. A current version holds about 400 litres of the agent. When it strikes the ground, the napalm is spattered over an elliptical area about 120 metres long and 25 metres wide. In this design, the napalm is ignited by a 0.6 kg. charge of white phosphorus, and generates a large, intensely hot fireball that lasts for about five seconds. This then subsides, but the napalm continues to burn for about five minutes. A single ground-support aircraft can carry several of these weapons under its wings.

45. Another aircraft incendiary weapon is the white phosphorus rocket. Rocket launchers are common armaments for ground-support aircraft. A typical launcher, of which several may be mounted on an aircraft, is capable of dispensing half a dozen or more 70 mm. calibre rockets. Different types of warhead may be fitted to the rockets. White phosphorus ones are used either as antipersonnel weapons or for smoke-marking purposes.

Ground weapons for use against battlefield targets

46. Although napalm was developed during the Second World War primarily for use in air raids on cities, its properties made it particularly suited for use in flamethrowers. Indeed, but for the development of napalm, the flamethrower, which previously dispensed heavy petroleum oils, would probably not have acquired its present status. There are two principal types: the portable and the mechanized flamethrower. The former, which a soldier can carry on his back, comprises a tank of napalm, a tank of compressed air (or some other propellant device), and a nozzle/igniter system through which the napalm is ejected. A typical present-day model weighs about 25 kilogrammes and holds about 15 litres of napalm. This it can throw to a distance of 50 metres in a single 8-second burst or in a succession of shorter bursts. Occasionally unthickened gasoline rather than napalm is used, but here the effective range rarely exceeds 20 metres. Wind conditions greatly affect the range of flamethrowers.

47. Mechanized flamethrowers are larger devices with longer ranges that are used either as auxiliary or as main armament or armoured fighting vehicles. A typical mechanized main-armament flamethrower has a napalm capacity of about 1300 litres, which it can eject in about a minute over a range of 200 metres.

48. Incendiary rockets fired from portable rocket launchers are beginning to replace portable flamethrowers in some of their tactical roles. One such rocket is a 66 mm. calibre missile, weighing about 1.5 kg., designed for a four-tube shoulder-fired launcher; it can be launched accurately to distances of up to 200 metres, or with poor accuracy up to 750 metres. It contains about 0.6 kilogrammes of a thickened pyrophoric incendiary, triethyl aluminium. Upon impact, the payload is spread over a radius of about 20 metres. Larger rockets of this type are being developed for use from armoured fighting vehicles.

49. Other ground weapons dispensing incendiary agents include land-mines charged with napalm or white phosphorus; artillery projectiles, mortar bombs or small rockets (i.e., up to 125 mm. calibre) charged with white phosphorus; and hand or rifle-grenades charged with white phosphorus or thermate.

Other incendiary weapons

50. Incendiary weapons have also been developed to meet certain specialized requirements that do not fall within the preceding categories. Noteworthy among them are the devices that have been designed for firing vegetation and crop cultivations. Targets of this type possess combustion characteristics that differ somewhat from the more normal targets of incendiary attack, and for this reason it has in the past been considered worth-while to develop special weapons. So far these efforts have not been notably successful. They are mentioned here because they represent a line of development that might be pursued further in the future.

51. One example of a special anticrop incendiary weapon is the small frangible bomblet for air delivery that contains a white phosphorus formulation such as one

of those described in paragraph 26 above. Another example is the so-called "leaflet incendiary". This comprises a small flake, or pair of flakes, of inflammable plastics material coated with an igniter composition containing white phosphorus that takes fire after being exposed to air. Several thousand of these weapons might be released by aircraft flying over crop cultivations.

52. Also to be noted are the various incendiary devices that are on the borderline of the terms of reference of this report. There are, for example, certain types of anti-aircraft artillery shell which contain both an incendiary charge and a high explosive one. There are also fragmentation weapons that dispense antipersonnel fragments of metal such as zirconium or depleted uranium that spark when they strike hard surfaces. The sparks may serve to ignite inflammable materials, particularly gasoline. 8/

8/ A further category of weapon that may be noted is the various air fuel-air explosive (FAX) devices that have recently found combat employment. A typical FAX weapon comprises a large air-dropped container that sets up a cloud of vapourized or aerosolized carbonaceous fuel (e.g., propane, butane or ethylene oxide), which it ignites after an interval corresponding to the period within which the cloud has become diluted by air to the point where it is explosive. Such weapons create strong blast waves, but when they malfunction they may create a fire-ball.

CHAPTER II

ACTION OF INCENDIARY WEAPONS AND THEIR NON-MEDICAL EFFECTS

53. Incendiary weapons may damage or destroy most types of material. They may initiate fires that subsequently take hold and spread through their surroundings. The present chapter describes the mechanisms involved, the factors that determine the spread of fire, and the damage that may be suffered from incendiaries in different types of material, in built-up areas and in the natural environment.

54. Four matters of particular significance emerge from the chapter:

(a) Incendiary weapons may severely damage structures, machinery and other items of equipment even where such targets are made predominantly from non-combustible materials. To take a battlefield example, napalm is capable of immobilizing armoured vehicles and putting other heavy weapons out of action.

(b) If a fire takes hold and spreads, it may soon become uncontrollable, bringing indiscriminate destruction to almost everything in its path.

(c) In built-up areas, the spread of fire depends largely on the density and nature of buildings in the area. Densely built-up zones where wood is the predominant building material are particularly vulnerable to spreading fires. Precautions can be taken that reduce the probability of fire spread, but they need to be extensive if they are to provide significant protection against heavy incendiary attack.

(d) In rural areas, the probability of fire spread is largely determined by the climate, the topography and the prevailing weather conditions. In some parts of the world, areas of wildland or cultivation may be very susceptible to incendiary attack; in others, they may suffer only the most local damage. The additional long-term ecological consequences, which could be severe, are largely unpredictable.

How incendiaries start fires

55. In order to understand how incendiaries can set fire to their surroundings, one may look first at the fire that burns in a household fireplace. Three materials are needed to make such a fire: paper and small twigs or bits of wood to provide the kindling; coal or logs to provide the fuel that generates the heat; and a match to ignite the kindling, which subsequently ignites the fuel. Despite its high burning temperature, the match cannot ignite the fuel directly because it cannot release sufficient thermal energy to raise the fuel to its ignition temperature. A combustible material takes fire only when vapours given off by it react so violently with oxygen in the air as to inflame, which is something they can do only when a certain temperature is reached. Before this can happen, energy has to be applied to the material in order to release the inflammable vapours. At room temperature, materials such as gasoline already emit large quantities of vapour. But a good deal of energy is needed before sufficient quantities can be forced out of coal or wood. Still more energy has to be applied to less combustible fuels.

56. The household fire in fact has a fourth essential component, namely, a supply of oxygen. This is, of course, derived from the air. The grate of the fireplace and its chimney are usually designed so that a continuous stream of air is drawn up through the fuel. Within certain limits, the greater the air draught, the more strongly will the fire burn. If there is insufficient or excessive draught, the fire may not burn at all.

57. Combustion may also proceed without flames being generated. When a household fire dies down, glowing embers remain. These consist of fuel that has ceased to release inflammable vapour, but which continues to be consumed in a form of burning known as "glowing combustion".

58. In the situation where an incendiary bomb falls on combustible materials, the latter are analogous to the fuel of a household fire, while the incendiary agent corresponds to the kindling, and the fuse and ignition system of the bomb correspond to the match. It is evident that if the burning incendiary agent liberates insufficient energy, the fuel will not take fire, and the bomb will prove ineffective. Much may depend on local air flows. Many instances are known where a fire smouldering along the floor or walls of a room suddenly bursts into flame as soon as a door is opened.

59. Three different processes may be involved in the transfer of thermal energy from a burning incendiary, or during the subsequent spread of fire, namely convection, conduction and radiation. Convection occurs when currents of air heated by an incendiary, or hot combustion gases, or the flame themselves, impinge upon surfaces in their path, heating them in the process. Hot air is less dense than cold air; it therefore rises away from the vicinity of the incendiary, the resulting air-movement forming a "convection current". New supplies of cold air are sucked into the blaze, sustaining or increasing its intensity. Convection currents may carry sparks or fire-brands with them, further aiding the spread of the fire.

60. Conduction is the process whereby heat is propagated through a material from a hot zone to a cold zone. When burning napalm sticks to a surface, the latter is heated mainly by conduction. Some materials conduct heat better than others, and poor conductors can serve as heat insulators. Because carbonized wood is a poor conductor, an incendiary agent with a high burning temperature may be less effective against wooden targets than one which burns at a lower temperature. The surface of the wood may become charred too fast to permit sufficient conduction of heat through it.

61. Hot materials release sizeable quantities of energy in the form of radiation. The hotter the material, the more energy it radiates. At temperatures above about 500°C, most materials become "red hot", which is to say that their emitted radiation has, among other things, become visible as red light. Materials also absorb radiation, and if they absorb more radiant energy than they emit, their temperature rises. Thus, a combustible material in the line of sight of a hot material may, if the latter is close or hot enough, become heated to its ignition temperature. The amount of radiation absorbed by a material rapidly declines with distance from the emitter. Nonetheless, the radiation emitted by a large mass of material at bright red heat may cause combustible materials many metres away to ignite. Radiation is probably the dominant mechanism in the propagation of fire along a row of detached houses.

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62. Intensive-type incendiaries, because of their high burning temperature and compactness, are powerful emitters of radiation, which is one of the main reasons why they may be effective against poorly combustible targets. Thermite and thermate incendiaries also spatter white-hot particles over their surroundings and liberate streams of molten iron, both of which may ignite nearby materials; for a small incendiary bomb, the area thus affected may be about 10 m^2. Heat transfer by convection, in the form of hot air currents or flames (in the case of thermate), is also important. Scatter-type incendiaries operate more by convection than radiation, and are therefore most destructive when the burning agent sticks to vertical surfaces. An explosive charge in the weapon distributes gobbets of burning agent (e.g., white phosphorus or napalm) which may then stick to walls, floors, ceilings, furniture, and so forth, creating numerous foci of fire. The agent may also penetrate into holes or fissures, creating hidden foci. The explosion may break down windows and doors, thereby increasing the air draught.

Spread and duration of fires

General features

63. Whether a fire takes hold and spreads through an area is a complex matter that depends on the interaction of many factors. Among them are the characteristics and distribution of the different types of material in the area, the prevailing weather conditions, and the local topography. In many situations, the wind velocity and the dryness or dampness of the target materials are particularly important. The behaviour of the fire also depends on the number and distribution of the foci from which it springs: to take an illustration from the Second World War, the scattering of large numbers of small incendiary bombs over a town was often more likely to burn it down than the same tonnage of larger bombs. Small bombs are, however, easier to extinguish than large ones.

64. An incendiary attack on a city is usually designed to create what is called a mass-fire. This occurs when the fires spreading from several foci merge into a single conflagration. This may then build up to an enormous and uncontrollable pitch of violence, only subsiding when virtually nothing combustible remains. Outside built-up areas, the point at which a spreading fire becomes a mass-fire is not clear-cut, but wildland fires intense enough to cover several square kilometres are generally thought of as mass-fires.

65. Mass-fires may be of two kinds. In one, the fire-front is moving, often with great rapidity, in the direction of prevailing winds. In the other, the fire is stationary, with very fast currents of air being sucked into it from all directions by the intense updraught created by the conflagration. This updraught has the same effect that a chimney has on a household fire, but on an enormously greater scale, so that virtually everything combustible in the area is consumed. Mass-fires of the second kind are known as fire-storms, and are even more destructive than the first kind. They are not known in wildland, only in urban areas, and even there they occur only under rare circumstances. 9/

9/ Some particularly violent mass-fires that have occurred in forests, or in such places as oil refineries, have, however, been referred to as fire-storms. This is largely a matter of terminology, as the point at which a mass-fire becomes a fire-storm is rather arbitrarily defined.

66. The factors that determine the behaviour of mass-fires are understood qualitatively but not quantitatively. More is known about the behaviour of the smaller fires that precede mass-fires. For these, much information is available on the types, sizes and dispositions of fuels that are critical to their spread. It is known that the total weight of fuel available is a factor of great importance. As the intensity of a fire increases, the burning time of a particular type of fuel decreases. The net result is an extremely rapid burn-out, with almost complete combustion of all combustible materials.

67. A mass-fire, whether or not it is a fire-storm, develops a tall and characteristic convection column comprising hot air, hot combustion gases, smoke and firebrands. Active heavy-fuel fires two or three square kilometres in area often produce convection columns that rise to 8,000 metres or more. The development of such a column increases the intensity of the fire, and for this reason mass-fires are dependent on weather conditions in the lower atmosphere.

68. As regards the duration of fires, there is a distinction, which is important for fire-fighting services, between "violent burning" and "residual burning" times. The former relates to the period when flames are at their height, and the latter to the period when they have largely given way to glowing combustion. 10/ For a fire in medium brush, for example, the violent burning period may last for about five minutes, with a residual burning time of about half an hour. Likewise, the violent burning time for a conflagration in a modern city centre might be about one hour, with a residual burning time of about two hours. The residual burning period is succeeded by a "potential threat" period during which the fire may again become active should the weather conditions change. For a medium brush fire, this period is unlikely to exceed two days but for a city-centre fire it might last for a month or more.

Wildland fires

69. The spread of fire through wildland is largely determined by the velocity of the wind and by the size, disposition and moisture-content of dead and living vegetation in the area. This fuel may be classified into three categories:

(a) Fine fuels, comprising dead or dessicated vegetation no more than a few millimetres in thickness. The moisture-content of such fuels closely parallels the prevailing relative humidity of the air;

(b) Medium fuels, comprising dead or living vegetation a few centimetres in thickness;

(c) Heavy fuels, such as logs, tree-trunks, or large branches.

10/ The violent burning time may be defined as the period when radiation exceeds 50 per cent of the maximum value reached. The residual burning time is the period when radiation is between 50 and 10 per cent of the maximum value.

Most wildland areas contain combinations of these fuel types. Ignition generally takes place in the fine fuels, and these, together with the medium fuels, then carry the fire. The fine fuels will not support combustion, however, when the relative humidity of the air rises much above 80 per cent. Moreover, it is doubtful, and dependent on the wind, whether the fine fuels will burn at between 40 and 80 per cent relative humidity. It is thus the first two fuel-categories that determine whether a fire starts and spreads; the third primarily determines the duration of the fire.

70. In wildland, the rate of fire spread increases with wind velocity. Winds affect fires primarily by assuring more complete and more rapid combustion, thereby increasing radiation. They also serve to dry out the fuels, thereby increasing combustibility. Ground-winds may fan the flames towards nearby fuels, and increase the number and size of flying firebrands, and the distance over which they are deposited (it is not uncommon in forest fires for firebrands to carry for a kilometre or more). Wildland fires sometimes spread more rapidly at tree-top level than at ground level; one reason for this may be the greater wind-velocity there.

71. Wildland fires tend to spread more rapidly in the daytime than at night. The relative humidity of the air is usually lower during the day, and the wind velocity is often higher. Because of their convection columns, wildland mass-fires are influenced by conditions in the lower atmosphere. Broadly speaking, the fire will spread more easily, and be more violent, if there is no inversion layer of cold air to impede the upward stream of hot gases. This could be another reason why fires tend to spread more rapidly during the day.

72. Detailed studies of wildland fires have been made in North America. Of those studied, the average velocity of the fire-front was 3.8 m/sec. Ten per cent moved faster than 8.3 m/sec. and 5 per cent faster than 13.3 m/sec. The observed velocities were usually independent of the size of the fire.

73. The facility with which fires may spread obviously differs in different climatic zones. In tropical rain-forests, for example, it is virtually impossible to create a forest fire, as experiments in tropical Africa and South-East Asia have shown. In contrast, in the tropical savannah, conditions may be highly favourable for fire spread. This is particularly the case for those parts of the savannah where the annual rainfall is sufficiently high to ensure vigorous growth of vegetation and where there is a distinct dry period.

74. The topography of the terrain has a significant, though usually indirect, influence on the rate of spread of wildland fires. It can, for example, control the amount and periods of incidence of solar radiation on the surface of a particular area. This affects the spread of fire through its influence on the local microclimate, in particular the local humidity and air-currents. Again, a fire may travel faster uphill than downhill; uphill, the rate of forward spread approximately doubles for each 15-degree increase of slope (presupposing, that is, that the fuel is the same on the different slopes, which is often not the case).

75. Wildland fires can become very large. Single fires traversing hundreds or even thousands of square kilometres can be of many days' duration. The cooling

period of a wildland fire can be very long. Forest fires have even been known to smoulder on all winter under a blanket of snow, becoming active again the following summer when the fuels dry out.

Urban fires

76. Concerning the start of urban fires, it is fairly well established that the moisture content of fine fuels in the interior of buildings is a determining factor, and that fuel dryness depends upon the humidity of the air in the building. In temperate zones, there is a correlation between outside dew-point temperature (in the winter), or outside relative humidity (in the summer), and the moisture content of fine fuels within a building. Generally speaking, however, the initiation of urban fires is less weather-dependent than the initiation of wildland fires.

77. There are several factors that determine how fires spread inside rooms, from room to room and from building to building. The initial phase of the fire is critical for its further development and determines whether extensive damage will result. It is therefore at this phase - during the initial spread of fire away phase may be quite short. A few minutes only may elapse before the combined heat production of the incendiary and of the materials it has ignited inside a room leads to a "flash-over" characterized by the sudden ignition of all combustible materials in the room. With this rapid upsurge of heat, particularly of radiation, windows break, admitting further supplies of air to fan the blaze.

78. Once one room in a building is burning in this manner, the fire soon spreads from room to room, upwards along stairs and ventilating shafts, and outwards through windows and other openings. The time taken for this to happen depends on the design and construction of the building. A wooden frame house may be enveloped by flames in less than half an hour; a brick building may still be saved from complete destruction even after one hour. Fire tends to spread upwards and horizontally through a building. The spread may be especially rapid along corridors or galleries that have combustible surfaces, a typical rate of spread along a wall-papered corridor being 4 to 5 metres per minute, increasing when doors or windows are open. Non-combustible surfaces may merely serve to conduct heat to more vulnerable areas. Downward spread, which is slower than upward spread, generally requires that a floor be burned through, burning fragments then dropping to the floor below. It follows that incendiary bombs tend to be more destructive if they succeed in penetrating through several floors of a building before igniting.

79. The spread of fire from one building to another usually follows the ignition of exterior surfaces, particularly roofs. Convection of flames and sparks, as well as heat radiation, may cause the actual transfer. This occurs most easily between adjoining buildings, but even where there is a gap of several tens of metres, a neighbouring house can be set on fire by thermal radiation. The projection of blazing firebrands may spread fire over still larger gaps, even up to distances of a hundred metres or more. In these ways, secondary fires are started by the primary fire when sufficient protective measures are not undertaken.

80. Once flames from burning houses begin to project into the open air, the subsequent spread of fire is largely wind-controlled. It is generally accepted that surface wind-speed is the most important weather factor influencing the spread of small urban fires. The wetness or dryness of the exteriors of burning buildings, and of buildings adjacent to them, has a certain effect, but not as a major determinant of fire spread. During the fire-raids on cities during the Second World War, wet weather served more to reduce initial ignitions than to impede fire spread. Precipitation seems to have had little effect on over-all fire-raid damage. In contrast to wildland fires, there seems to be little difference between the night-time and the daytime rate of spread of urban fires.

81. The mechanisms of spread are more complicated for urban fires than for wildland fires. Much depends on the way the buildings are constructed and situated in relation to one another. The constructional features of greatest importance are height, width, type of construction material, window area, and separation from adjoining structures. The latter is perhaps the most important of these; the presence of wide gaps between buildings greatly reduces the risk of mass-fires developing in urban areas. For a situation in which many small fires are initiated in an urban area, it has been calculated that for an average gap of 8 metres, the probability of fire spread is about 80 per cent. This falls to 40 per cent for an average gap of around 25 metres, and to about 7 per cent for one of 65 metres.

82. Concerning the other constructional features, the probability of fire spreading across a given distance is greater for a denser and heavier fuel area than for a sparse and lighter one, assuming that the spacing between buildings is uniform. The heaviness and density of the fuel contained in an area may differ widely in different regions of a town or city. Light residential zones, for example, may differ substantially in these respects from industrial zones.

83. Urban mass-fires may occasionally take the form of fire-storms. In a fire-storm, the induced inrush wind-velocity (25 m/sec. or more) exceeds that of the prevailing wind, thus preventing any significant spread outside the periphery of the fire, and causing it to burn more intensely. The convection currents rising from many small initial fires combine into a central vertical column as the flames from fires in different buildings merge into a single enormous blaze. From a distance, the convection column appears to be a continuously rising stream of smoke and other combustion products. Viewed close to the fire, it can be seen to be made up of a number of smaller columns developing over relatively small "hot spots" of active fire. These convection columns merge some distance above the fire to form the single-column appearance of the distant view. The water-vapour carried up in the column eventually condenses around smoke particles and falls back again, so that fire-storms are accompanied by what seems to be rainfall. The temperature in a fire-storm area may be around 1500°C, and the fire-storm may continue for three to four hours.

84. Fire-storms are considerably more destructive than other urban fires and cause a much greater loss of human life. They rarely, if ever, occur naturally, and even during massive incendiary air raids they have proved uncommon. In Germany, scores of cities were subjected to fire-raids during the Second World War, but fire-storms occurred in no more than five of them. In Japan, the incidence was still lower; it

is possible, in fact, that no fire-storm occurred there except the one that followed the atomic bombing of Hiroshima. Many attempts were made to initiate fire-storms during the war, but it often happened that the fires started by the incendiaries soon burnt out at or near their point of origin, even without fire-fighting efforts.

85. The pre-conditions for a fire-storm are not well understood. It is known that the percentage of ground area that is covered by buildings is critical to the probability of a fire-storm developing. If it exceeds 50 per cent, a fire-storm could occur (if it exceeds 25 per cent, there is a risk of the other type of urban mass-fire). Other requirements seem to be a large number of nearly simultaneous ignitions in the target area, little or no ground wind, and unstable atmospheric conditions.

86. Fire-fighting in a city subjected to incendiary attack is a very difficult undertaking and in some cases its results may be marginal at best. It is essential that the fire-fighting process be started as early as possible. The extinguishing of burning magnesium bombs using sand or earth, for example, is not difficult, but as soon as the fire begins to take hold in the city the fire-fighting problems will rapidly become insurmountable. Because incendiary weapons are likely to be used in large numbers against a city, fire-fighting also is a quantitatively demanding task. Once a mass-fire has started, fire-fighting efforts may be successful but only at the fringes of the fire zone. Within the fire zones, the safety of the inhabitants can, of course, be best assured by evacuation. If this is not possible, shelters may have to be relied upon, but to be effective in protecting people against mass-fires these need to be elaborate and, in most cases, specially constructed. They need a concrete or similar roof of around one metre in thickness in order to prevent heating of the air inside the shelter. A closed system of oxygen supply will also be needed in order to support respiration and exclude asphyxiating combustion products. Shelters like this usually do not exist in cities.

87. Different kinds of precaution against fire can be built into a city. Measures which reduce the risk of mass-fire can be incorporated when city areas are built, although some of them may be costly or otherwise undesirable. These measures include wide spacing between buildings and the construction of fire walls within the buildings. The careful choice of building material is important; and a small window area may also reduce the probability of fire spread. There should also exist an effective and well-trained fire-fighting service which is well equipped. All of these measures are useful also for peace-time fire protection. Some of the measures, however, may be very costly undertakings, while some, such as a small total window area, may be socially undesirable in peacetime.

General effects of fire

88. The mass-fire environment is a complex and changing one. Above all, it is intensely hot. All of the damage that it causes in buildings and material, and much of the damage it does to life, will be due to heat. Temperatures in excess of 1100°C can be expected within, immediately above, and downwind of strongly burning

structures. Maximum temperatures in natural free-burning fires have yet to be recorded; but they can be expected to be around 1500°C in those fires which burn intensely with a high rate of fuel consumption. Temperatures drop off rapidly with distance from a burning structure, particularly on the windward side, and remain at their maximum only for short periods. Hot fires generate powerful convection currents which may appear as strong ground-winds of varying velocity. In a fire-storm, the currents may be strong enough to sweep people off their feet and suck them into the blaze.

89. A large, strongly burning fire consumes oxygen in vast quantities. Particularly inside buildings, or in places where ventilation is at all restricted, this may deplete the local air to the point where human or animal life may be endangered. The simultaneous generation of large quantities of carbon monoxide and dioxide, and of smoke, add to the over-all asphyxiating effects. People sheltering in the cellars of burning buildings run a particularly high risk of becoming asphyxiated.

90. As oxygen levels fall during the fire, increasing concentrations of carbon monoxide build up. These arise from incomplete combustion of carbonaceous fuels. Complete combustion results in carbon dioxide and water, plus certain other gases and vapours if the fuel contains elements other than carbon, hydrogen or oxygen. If there is insufficient oxygen present, carbon monoxide is formed along with carbon dioxide. A toxic hazard is therefore created, and this may become acute over wide areas, particularly in confined spaces. A substantial proportion of the air-raid victims of the Second World War died from carbon monoxide; on some occasions this led observers to suppose that chemical warfare agents had been employed. Other toxic gases, vapours or smokes may appear depending upon what is burning. Plastics materials can generate a variety of dangerous combustion products, as noted in paragraph 94 below. A burning rubber warehouse might produce hydrogen sulphide and sulphur dioxide. A burning wool mill might produce hydrogen cyanide. A factory making organochlorine products (e.g. polyvinyl chloride) might generate chlorine and hydrogen chloride. Some of these combustion products are even more poisonous than carbon monoxide.

Specific effects of fire on matériel

91. The heat generated by incendiary agents, or during conflagrations, is capable of bringing about profound physical and chemical changes in most materials. The resultant damage is not confined to materials that are combustible.

92. Metal construction materials such as steel, cast iron and aluminium alloys do not generally take fire, mainly because there is usually insufficient oxygen present. Chemical changes may occur, such as oxidation, but they are confined to outer surfaces. The main effect of heat on metals is to cause softening and loss of mechanical strength. Aluminium structures, for example, begin to lose their rigidity at temperatures of 200-250°C, and melt at around 660°C. Loss of strength stems from alterations in the crystal structure of the metals; this is what happens, for example, when the temper of hardened steel is lost during slow cooling after a period of intense heating.

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93. Wood is composed mainly of cellulose, which is a natural polymer, together with lignin, hydrocarbons and other substances. Dry wood usually contains around 10 to 15 per cent of water. When heated, a complex series of changes takes place in the wood, among them desiccation and distillation of the various volatile organic substances that produce the flame. Once the wood has begun burning, the additional heat generated accelerates the decomposition and carbonization of the cellulose. The final stage is glowing combustion of the resultant wood charcoal.

94. Synthetic polymers are widely used industrially, in construction materials, in various types of machinery and electrical equipment, and in clothing, furnishings, and so forth. They vary in their response to heat, but most of them soften at relatively low temperatures. Such widely used plastics as polyethylene and polyvinyl chloride soften at temperatures of around 100°C or less. Decomposition usually sets in at around 250-300°C, although some polymers can withstand considerably higher temperatures. The decomposition products may include volatile, inflammable substances, in which case the polymer is likely to catch fire. They may also include a variety of toxic chemicals. Carbon monoxide is generated by many burning polymers, while hydrogen chloride may result from some (e.g. polyvinyl chloride) and hydrogen cyanide from others (e.g. the polyurethanes).

95. Few, if any, buildings are immune to damage by fire. Whatever they are made from they invariably contain combustible furniture and fittings. If these catch fire, and the fire then spreads, even the most fire-resistant materials may not excape damage from the resultant heat. Steel girders may buckle and lose their strength; sheet-metal facings and panels may warp and melt. Concrete and stone may crack. Mortar may disintegrate, and brick or masonry constructions crumble.

96. Vehicles are particularly vulnerable to fire. Their upholstery, for example, is often highly combustible, and fire may soon spread to the petrol tank. Even military vehicles, which are generally better protected than civilian vehicles, may be destroyed or immobilized by fire. Armour-piercing weapons may inject incendiary materials into the vulnerable interior of armoured vehicles. If agents such as napalm are directed against them, hot air or flames may be sucked into engine compartments by air-cooling systems, where they may ignite rubber components or leaks of engine oil. Likewise, combustion gases or flames may be sucked into the carburation systems where they may not only prevent an adequate oxygen intake into the engines, but may also ignite the fuel supply. The radiators of the vehicles may crack under the influence of the heat, releasing their cooling fluids and eventually precipitating engine failure, if this has not already occurred.

97. Machinery and other equipment may likewise suffer severe damage from fire. Metal components may twist under the influence of heat. Tempered steel may be rendered brittle. Functional metal surfaces may become oxidized, losing their finish. Electrical equipment is especially likely to break down. Valves may burst; transistors may cease to be semi-conducting; and insulating materials, if they are not inflammable, may melt or crack and fall apart. The consequences of damage of these types may range from the destruction of individual weapons or factory tools up to the breakdown of public utilities or the dislocation of great communication networks.

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Specific effects of fire on the natural environment

98. As noted in paragraphs 69-75 above, fires may propagate themselves rapidly across wide tracts of countryside under certain climatic conditions and in certain types of vegetation. Wholesale destruction of crop cultivations and of other means of subsistence may result from this. Large-scale fires may also have the longer-term ecological consequences that are described below.

99. The destruction of trees and similar forms of plant life may disturb the mineral and water balances of the local soil by interfering with transfer cycles. Root formations that previously maintained the soil structure may wither away. These factors, together with the scorching effects of the fire on the soil and its microflora, may adversely affect the bulk density, water storage capacity and aeration of the soil. The soil may no longer be able to acquire or retain its nutrients, and its quality may deteriorate, while in some areas there may be a serious risk of erosion of the topsoil, either by wind or by water. Previously fertile areas may thus be rendered barren.

100. The elimination of a plant species from an area through the action of fire may be succeeded by invasion of the area by a different species. Coarse grass may take hold in soil that has been too badly damaged to support more demanding species. The removal of the leaf canopy in forest areas may promote the growth of brush otherwise held in check. Invasions of bamboo, for example, are particularly common in fire-cleared areas of certain tropical forests. Similar effects may be observed in the fauna of areas affected by fire. One common characteristic of burnt-out forest areas is their rapid colonization by different insect species. These may constrain further regeneration of plant life and may, under some circumstances, lead to the establishment of new foci of human or animal disease.

101. It should be noted that the ecological changes wrought by fire in an area may sometimes be beneficial. Swidden cultivation, in which ground left fallow for several years is cleared with fire prior to short periods of cropping, has been practised from antiquity in wide areas of the world. Likewise, in several countries the use of fire as a tool in forest and pasture management is increasing. These applications of fire are closely controlled, however, or are guided by traditions that embody the experience of centuries. They are practised for specific and limited objectives, and in areas where they are known to be beneficial.

102. Under less controlled, or less familiar, conditions, the extensive use of incendiary weapons in rural areas, whether or not it is intentionally directed against cultivations or similar targets, may well produce wide-ranging destruction. In the short term, harvests may be lost on which the livelihood of large numbers of non-combatants depends. In the long term, depending upon the largely unpredictable outcome of the resultant ecological changes, irreversible damage may occur which has little or no bearing on the objectives for which the weapons were used in the first place. Measures for remedying the damage may prove too costly to be undertaken. Severe and long-lasting hardship may then be added to the afflictions of the local population.

CHAPTER III

MEDICAL EFFECTS OF INCENDIARY WEAPONS ON INDIVIDUALS AND POPULATION

103. This chapter is concerned with the effects of incendiary weapons on people. The first section describes the direct effects that burning incendiary agents or heat can have on the human body. The second section describes the additional medical consequences for people who become caught in fires created by incendiary weapons. The final section outlines the types of medical aid that burn casualties require, and the problems involved in providing adequate treatment.

104. The main features of the chapter may be summarized as follows:

(a) Burn injuries differ from the wounds commonly caused by conventional weapons in the exceptional difficulty of their medical treatment. In conflict areas where medical resources are modest, casualties from incendiaries such as napalm have little chance of receiving effective medical aid.

(b) Although published information is scanty, napalm weapons appear to produce an exceptionally high proportion of deaths among their casualties compared with other weapons. Whether mortal or not, napalm injuries, like other burns, may be intensely painful, both when they occur and during some or all of the subsequent period.

(c) Recovery from burn injuries is slow, and during most of the period the patient remains in great pain. Napalm and white phosphorus burns are likely to leave him deeply scarred and disfigured for the rest of his life.

Direct effect of incendiaries on individuals

Types of burn injury

105. Skin is easily damaged by heat, the degree of damage depending upon the amount of heat. In medical practice, different categories of burn are distinguished according to their depth, their extent and their cause. The classification of a burn injury into a particular category - "first degree", "second degree", and so on - indicates the depth of the burn and this together with its extent determines the type of medical treatment which is required.

106. Normal skin comprises a number of layers, and the severer the burn, the deeper are the layers that are damaged. The outermost layers, which constitute the epidermis, include dead or dying cells that are continuously sloughing off and being replaced by new cells growing up from below. The dying cells become compacted into a tough outer layer which gives the epidermis its strength. The innermost layers of the skin form the dermis. Here, in a dense bed of connective tissue containing nerves and blood vessels, are located the hair follicles and sweat glands that provide a source of regenerating young cells that grow upwards

to replenish the epidermis. Underneath the skin is a layer that contains blood vessels, fat and nerves, and which links the dermis to the deep tissue of the body.

107. First-degree burns represent relatively little damage to the skin. Mild sunburn is a first-degree burn. There is pain, but it passes quite quickly. White skin reddens, but blisters do not form. First-degree burns are usually followed by a peeling of the superficial layers of the epidermis. This is completed within a few days and leaves no scar.

108. Second-degree burns kill tissue both in the epidermis and in the dermis, although without damaging the hair follicles and sweat glands. Blisters form at the interface between the dermis and the epidermis. In the absence of complicating infections, the injuries heal quite quickly with new skin tissue growing back from the hair follicles and sweat glands. Mild second-degree burns (e.g. sunburn with blistering) heal without scarring in about a fortnight. Severer ones take longer because more tissue has to be restored and because there is more dead tissue that has to detach itself from the living in order that regeneration may occur. Moreover, deep second-degree burns are unlikely to heal without producing scars. Second-degree burns are always intensely painful, and remain so during much of the healing process.

109. Third-degree burns destroy the full thickness of the skin, including the hair follicles and sweat glands. In some cases, uncontrolled infection of a deep second-degree burn may convert it into a third-degree burn. The burned tissue is dry, and dark red or black in colour. Blisters rarely form. The sensory nerve endings are destroyed, so that there is no sense of touch. There is often attendant coagulation of fat, muscle and other deep tissue, which may later result in severe scar contractures and deformities. In peacetime practice, surgeons find it sufficient to use the above classification of burns. The use of napalm in war has, however, led to an increase in the number of deep burns and experience in treating them. In the process of triage of such burns, doctors have established the special category of fourth-degree and even fifth-degree burns. These relate to burns that completely char the skin and extend into the deep tissue of the body, damaging the musculature and reaching to the bones and internal organs.

110. The threat to life of second- and third-degree burns for the injured depends on the extent, depth and localization of the burns and on a number of other factors, the principal one being the quality of, and accessibility to, medical aid. People with 40 per cent burns have a chance of survival if they are given all possible medical aid in specialized burn hospitals, but if more than 60 per cent of the surface is burned they usually die. 11/ For people who do not receive this degree of medical aid, however, and for people above middle age, these figures become lower.

11/ It is relatively easy to gauge the percentage of a man's body surface that has been burnt, for the body is made up of approximately 9 per cent units: 9 per cent for each arm (including about 1 per cent for the palm and fingers of each hand), 18 per cent for each leg, 9 per cent for the head, 18 per cent for the back and 18 per cent for the front.

111. Third-degree burns, and deep second-degree burns that cover more than 10 to 15 per cent of the body surface, have a profound effect on the entire body, not merely on the afflicted areas of the skin. The victim is likely to go into a state of shock characterized by a grave and sometimes mortal derangement of the circulation (see paragraph 116 below). In addition, toxic effects are likely to develop as poisons generated in the burnt area are carried around in the blood circulation. Moreover, there is always a severe risk of infection of the burned tissue, the injuries becoming septic and filled with pus, and this also may have mortal consequences. Because of his injuries, the victim may be unable to eat, and even if he can, he will probably not wish to, through lack of appetite. Extreme malnutrition may then develop to exacerbate the consequences of protein loss from destruction of tissue and seepage of body fluids at burn sites. A badly burnt patient who survives is often in so weak a condition that such measures as skin grafting have to be delayed for many weeks.

112. People exposed to flames and heat may also suffer respiratory burns. Inhaled hot gases may cause the lining of the respiratory tract to swell and obstruct the breathing passages. The situation is still more serious if the hot gases penetrate into the lungs, for here they may easily destroy the tissues that control oxygen uptake by the blood. The inhaled combustion products may also exert a significant toxic effect. Respiratory burns are one of the four main causes of death in burn casualties, the other three being the shock, infection and malnutrition described above.

Effects of napalm and related incendiaries

113. Napalm may burn, asphyxiate or poison its victims. Its adhesiveness, high burning temperature and prolonged burning time lead to deep burns. The asphyxiating and toxic effects, when they occur, stem from the combustion of oxygen in the local air, from the heat of the combustion products, and from the large amounts of carbon monoxide that are generated in the process. Toxic effects may also arise directly from the white phosphorus that is frequently present in napalm.

114. It must be stated that, despite the large quantities of napalm that have been employed in war, the medical literature so far contains rather little information on the direct effects of napalm and its combustion products on the human body. One team of surgeons serving in a civilian hospital in an active conflict area in South Viet-Nam during 1966-67 have remarked that napalm is an "all-or-nothing weapon". Because of the infrequency with which they saw napalm burns, they concluded that its victims were more likely to be killed than to require medical aid. 12/ Another field of observation made among the victims of napalm attack suggests that about a third of the casualties are likely to die within half an hour.

12/ H. A. F. Dudley et al., "Civilian Battle Casualties in South Viet-Nam", British Journal of Surgery 55: 332-340, 1968.

An additional, and higher, proportion are likely to die within the next 24 hours. 13/ If this is so, napalm must be one of the most lethal weapons in existence today.

115. The principal characteristic of napalm burns is their combination of depth and multiplicity. In the manner in which the agent is commonly employed, it is scattered over its target in large gobbets. This means that people occupying the target area, if they are hit at all by the agent, are likely to be hit by a substantial mass of it. Moreover, what also tends to happen is that when they try to remove the napalm from their skin, or strip off their burning clothes, they spread it over other parts of their bodies, particularly their hands. Some field observations made among the victims of napalm attack tend to indicate that more than a quarter of the people struck by napalm during the types of napalm attack conducted today are likely to suffer burns over more than 25 per cent of their body surface. Around half of these burns are likely to be of the fourth degree. 13/

116. Napalm burns are particularly likely to induce a state of shock. This is a condition of the body in which the tissues are poorly perfused with blood because of a derangement in the circulation. In severe cases of shock, the supply of oxygen reaching such organs as the brain, heart, liver and kidneys may drop below life-sustaining levels. There are different types of shock. "Neurogenic" shock may succeed pain, fright or other sudden emotional distress. The intense pain that burning napalm causes and the experience of being unable to extinguish it when it sticks to the skin are most probably the two main reasons for its frequent occurrence among napalm-burned victims. Therefore analgesic drugs must be administered as soon as possible. "Hypovolemic" shock is caused by a lowered blood volume due, for example, to loss of blood or plasma from a wound or burn; here the effects may not be transient, for they can be reversed only by repletion of the blood volume. Napalm victims exhibit both these types of shock, this probably being the major cause of death among those who die quickly. In contrast to conventional burns, shock may sometimes accompany relatively small napalm burns, even those of the second degree.

117. In addition to shock, carbon monoxide poisoning may be a second contributory factor in the high and rapid mortality among napalm victims. When carbon monoxide enters the blood after inhalation, it has the effect of combining with the blood component that carries oxygen around the body. This component, haemoglobin, has considerably greater affinity for carbon monoxide than it does for oxygen. This means that even small quantities of inhaled carbon monoxide can deprive the body of the oxygen it needs for survival, thereby provoking death in a matter of minutes. Carbon monoxide levels above about 5000 mg/m^3 are probably lethal if inhaled for more than a minute or two. Sublethal exposures to the gas can result in permanent injury to the central nervous system and the heart, as a consequence of temporary oxygen deprivation. According to one report, 5 per cent of those who recover from napalm injuries continue to suffer from the extended effects of carbon monoxide poisoning.

13/ Private communication from Dr. Jiri Franek.

118. In addition to shock and carbon monoxide poisoning, respiratory burns are the third major contributory cause of deaths from napalm. Napalm victims are likely to inhale large quantities of hot air and combustion products. They may then be asphyxiated, either because their respiratory passages become blocked by swelling and inflammation, or because the tissue controlling oxygen uptake in the lungs is destroyed or because of other toxic effects. Damage to the lining of the respiratory tract also opens the way to massive bacterial infection that may itself prove lethal.

119. A further factor that contributes to the high mortality rate among napalm casualties is the difficulty and complexity of the medical treatment which burn injuries require. This treatment is described in paragraphs 134-140 below. The organization of facilities, supplies and medical personnel for the treatment of substantial numbers of burns is a complicated undertaking in any circumstances, and in countries where medical resources are limited it may prove virtually impossible. If napalm is used extensively in such areas, napalm casualties may have little chance of receiving medical attention in time.

120. The burns of napalm casualties who do not die rapidly are likely to become heavily infected. The damaged tissue provides a culture medium that is particularly favourable to the growth of bacteria (as is shown by the foul smell and large quantities of pus displayed by untreated burns). The bacteria and toxins produced by them may enter the blood circulation, with general sepsis then becoming a major contributory cause of death. The casualties are also likely to develop severe anaemias through destruction of red blood cells in the burn sites. They may also suffer massive loss of blood plasma through oozing and collection in the coagulated areas of the burns. Secondary shock and kidney failure due to low blood volume are common. Toxicity from phosphorus particles (see paragraph 123) present in the napalm adds an additional liability to the already highly-stressed casualty, and further impairs his ability to survive.

121. If he stays alive through the first day, a badly burned napalm victim will remain in a critical state for the next 30 to 40 days. During this period, his progressing malnutrition, his susceptibility to infection, and the other complications referred to above, will often result in death despite intensive medical care. Less than 20 per cent of such casualties are likely to last through to the period of convalescence, which itself will be arduous and painful. They will then have to come to terms with their deformities and disabilities and the grave emotional consequences that these will inevitably have for them.

Effects of white phosphorus

122. White phosphorus, like napalm, commonly produces deep burns that may sometimes be very extensive. The agent is usually scattered as a mass of sticky particles, and each of these may adhere to a person's skin, continuing to burn until isolated from air or fully burnt out. The result is a multiplicity of relative small burns that extend deep into the skin over a large surface area and often into the underlying tissue. Burns of this type are extremely difficult to treat. Phosphorus particles that eat their way down into the musculature may lead to a

loss of motor function that may be irretrievable, and which will certainly pose great rehabilitation problems. Phosphorus burns of the hands, wrists or feet, for example, may (like other deep burns) result in partial or total disablement of these extremities after healing.

123. Phosphorus lodged in the tissue may produce systemic poisoning after entering the circulation. It is a powerful protoplasmic poison, and as such it may damage all vital cells that it reaches. This can have many consequences, several of them potentially lethal, notably the damage to the liver, heart, kidneys and the organs that generate blood cells. Whether these toxic effects are manifested, however, depends on the extent to which white phosphorus is absorbed into the circulation from surface wounds, and while it is known that this can happen, relatively little is known about the facility with which it occurs. However, in view of the frequency with which a lowered white blood-cell count is observed among white phosphorus casualties, it appears that the toxic properties of the agent contribute significantly to the injuries that it causes. Toxic damage to the organs that generate blood cells is a particularly menacing complication of burn injuries. On the one hand, a decrease in the rate at which the body generates new red blood-cells will compound the anaemia developing from the burn sites; on the other hand, a decrease in the number of white blood cells reduces the ability of the body to resist infection and this also increases the vulnerability of the victim to his burns.

Effects of other incendiaries

124. Thermite and thermate incendiaries, when they burn, scatter droplets of molten iron. People in their immediate vicinity are therefore likely to experience a multiplicity of small deep burns, with particles of iron lodged in the skin. Similar effects are produced by magnesium incendiaries, particularly those that incorporate an explosive charge. Magnesium may become deeply embedded in the tissue, causing localized formation of hydrogen gas, with consequent tissue destruction.

Effects of conflagrations on populations

125. People may die or suffer injury during incendiary attacks both from the direct effects of incendiary agents that have just been described, and from the indirect effects that result from the fires which the incendiaries initiate. As described in paragraphs 88 to 90, additional hazards to human life develop in the course of such fires, but in the main their effects do not differ in kind from the direct effects of incendiary agents, although they may differ in degree. The principal threats to human life during conflagrations remain those of thermal injury, poisoning and asphyxiation.

Physical effects

126. From the point of view of the effects on the human body, an extremely high environmental temperature is the principal characteristic of mass-fire. This will lead to a large number of deaths from asphyxiation, caused by thermal damage to

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the respiratory tract. It will also lead to burns that range in intensity from those of the first degree among people on the periphery of the blaze, up through second, third, fourth and fifth degree, to the grisly phenomenon of the charred and shrivelled corpses that were found in large numbers after some of the Second World War fire raids.

127. Air raid shelters commonly failed to provide the inhabitants of cities with protection against massive fires caused by incendiary attacks during the Second World War. Insufficient thermal insulation often meant that the shelters became lethally hot. Incidents are recorded when, as the doors of the shelters were opened some days after a fire raid, there was enough residual heat for the entire shelter to burst into flames under the influx of oxygen. People who did not enter air raid shelters often had a better chance of remaining alive than people who did, for the flames raging in the surrounding areas tended to suck the air out of the shelter, replacing it with a lethal mixture of carbon monoxide, smoke and other combustion products.

128. Some of the large-scale incendiary bomb attacks on cities conducted during the Second World War proved as destructive as the atomic bombs dropped on Hiroshima and Nagasaki. Wide expanses of built-up areas were razed to the ground, the collapsing buildings and other falling debris causing mass incidences of surgical injuries in addition to the thermal casualties. On average, there were 20,000-30,000 casualties in each German city subjected to major air raids. Sixty per cent of these casualties remained alive and in need of medical aid. The consequences of an incendiary attack on a population centre may therefore be catastrophic, with the number of people needing medical attention far exceeding the resources available for providing it.

Psychological effects

129. Most human beings seem to have an inbred fear of fire, and the psychological effects of incendiary weapons are commonly listed among their military attractions. During mass-fires, large numbers of people may become trapped by great walls of flame that seem to spread in all directions, offering no possibility of escape. The use of agents such as napalm or white phosphorus, which cling to surfaces and to fleeing people while burning, cannot fail to increase the over-all psychological impact. Coupled with a general breakdown of communications and public utilities and services, the result could well be mass panic, with all its consequences for survival procedures that might otherwise be effective.

Other considerations of medical significance

130. The widespread destruction of dwelling-houses and shelters will compound the difficulties of providing adequate aid for fire-raid victims, for in a hostile environment exposure to the weather will increase over-all suffering and loss of life. This situation is likely to be worse in the developing countries than in the developed, for not only will lesser medical resources be available, but widespread malnutrition, chronic anaemias and other deficiencies will increase susceptibility to exposure.

Medical countermeasures against incendiary attack

131. The proportion of burn casualties among the victims of war has been rising steeply. During the nineteenth century, burns probably accounted for no more than one per cent of battlefield injuries. The figure was not much higher during the First World War, although in some armies special field hospitals were organized to handle the severe injuries that burn casualties usually presented, and the abnormally complex treatments that they required. During the Second World War, the proportion increased, due mostly to the petrol burns that were an inevitable consequence of mechanized warfare. The Second World War also brought with it a sharp increase in the proportion of non-combatant casualties among the victims of war, a trend which has not been reversed in subsequent conflicts. In part this is because military action has increasingly been directed against civilian targets, or military targets in the deep rear. In part it is because of an increasing reliance upon area weapons, which, by their indiscriminateness, are especially likely to harm non-combatants living around their targets. Incendiaries have proved to be one of the most destructive and widely used weapons in the attack of urban targets. They have also become increasingly relied upon in recent conflicts as battlefield area weapons, particularly fire-bombs containing napalm. For these reasons, burn injuries are no longer a problem of relatively minor importance in wartime medicine and surgery; they are now a major determinant in the wartime deployment of medical resources.

132. The successful treatment of burn casualties is a long-drawn-out process that requires great skill and patience from medical practitioners, and extensive supplies of different medicaments and equipment. If there are deficiencies in any of these respects, the chances of badly burned incendiary victims surviving will not be high. When medical resources are limited, the process of triage will generally mean that such casualties are, of necessity, left to die.

133. There are six distinct phases in the medical treatment of a burn casualty. They are outlined briefly in the following paragraphs to indicate the great complexities involved. The description relates primarily to napalm victims, but much the same applies for casualties of mass conflagrations or of other incendiary weapons. In the case of white phosphorus burns, the process is, if anything, more complicated; special efforts have to be made, for example, to remove phosphorus particles that are still burning from the flesh.

134. The first phase is the transport of the victim to a medical aid post. A man in a state of shock, as he might be even from mild napalm burns, may be helpless and too weak or fearful to move. If he can, his powers of endurance will be small, so that unless he receives help he may never reach the aid post. Even if he does reach it, the treatment of his injuries may well prove beyond the medical resources available, particularly in remote rural areas.

135. The pain, which is in part responsible for the initial (neurogenic) state of shock, must be relieved by analgesic agents, such as morphine. The secondary (hypovolemic) shock that develops from the loss of body fluids at the burn area must then be controlled, together with the consequences of the toxic products of

burnt tissue that enter the blood circulation. For a week or more, therefore, continuous transfusions of blood plasma, whole blood, and other fluids, will have to be made into the patient's veins, under careful and continuous monitoring to ensure that appropriate levels are being maintained, including urine rates. Respiratory support will also be needed. These are onerous requirements, particularly the need for whole blood and blood plasma. Even in the developed countries, blood supplies are difficult to mobilize, and in the developing countries the requirements of refrigerated storage, typing and cross-matching before infusion may well prove far beyond available capabilities.

136. While this is continuing, stringent measures need to be taken to prevent the burns from becoming infected. The first step is the immediate cleaning of burned areas, and their dressing with topical antibiotic preparations. Scrupulously aseptic procedures must be used throughout. Burnt tissue must be debrided (cut away) in order to allow new tissue to regenerate, and fresh applications of antibiotics must be made over the area. All of this will be intensely painful for the patient, and will require the use of anaesthetics, if they are available. Amputations may have to be performed if extensive charring has occurred and infection cannot be checked. If infection is held back - and the chances of this are not high even in the most carefully equipped field hospitals - skin grafting may then be undertaken. This must be extended over a prolonged period in order to avoid taxing the patient's strength: the removal of skin from unburnt areas for grafting purposes itself amounts, in effect, to a first or second-degree burn injury.

137. Meanwhile the patient will require careful metabolic support. The loss of protein at burn sites must be compensated with special nutritional supplements. During the early stages, when the patient may be unable or unwilling to take food, this may have to be administered intravenously. Thereafter, his diet will need continued control as he progresses towards convalescence over the subsequent weeks.

138. The fifth phase in the treatment, reached when the patient is convalescent, is that of late reconstruction and rehabilitation. This involves the use of surgery to release flexion contractures in the skin, and to restore function to extremities and other organs. This phase is a prolonged and painful one.

139. Finally the patient must be given emotional support to sustain him through the long period of pain and isolation, and above all to assist his psychological adjustment to extensive scarring and other deformities. The emotional impact of altered appearance and disability can have a drastic effect on the victim's personality. Patients with extensive disfigurements are inclined to withdraw from contact with society because of the reaction their appearance generates in others. Their psychological injuries may remain with them for life.

140. It may be estimated that the requirements for treating a thousand wartime casualties having 30 per cent burns would include 8,000 litres of plasma, 6,000 litres of blood, 16,000 litres of Ringer's lactate solution (a balanced salt solution), 250 trained surgeons and physicians, and around 1,500 skilled

attendants. Each patient would require a hospital bed for anything up to four or five months. The degree to which the area in which the casualties occur, or to which they might be transported, can fulfil these requirements determines the proportion of the casualties that could be expected to survive. Success would be proportional to the facilities and supplies available. Even in the developed countries, the requirements would be difficult to mobilize on any scale; in the developing countries they might be far beyond available resources.

CHAPTER IV

INDENDIARY WARFARE AND ITS CONSEQUENCES

141. This chapter begins with an account of the different forms of incendiary warfare that have been practised in the past, and which continue to be practised in the present. When used in large quantities against urban areas, incendiary weapons have proved to be among the most powerful means of destruction and devastation known. Against battlefield targets their military attractions, particularly those of napalm, reside mainly in their use against strong-points, tanks and similar matériel, and in their casualty effects against enemy soldiers, particularly when the precise location of the latter is unknown. In this regard, their area effectiveness is a military benefit, albeit one that introduces a substantial degree of indiscriminateness. The concluding part of the chapter describes the social and economic consequences of incendiary warfare. Attention is drawn, among other things, to the marked disparity between the abilities of the developed and the developing countries both to inflict and to repair the economic damage that may result from large-scale incendiary attack. It is also noted, however, that as between warring countries that do not possess substantial military or economic resources, incendiary weapons such as napalm may possess particular attractions because of their relative cheapness.

Incendiary warfare prior to the Second World War

142. The development of incendiary weapons, like that of most other modern armaments, has been progressing for many centuries. So also has their use. Their relative importance compared with other weapons has risen and declined at different times and in different parts of the world. Looking back over the past, it seems clear that for some military purposes they are now in a new period of ascendancy.

143. Fire is an ancient accompaniment of warfare, and has regularly been used to lay waste enemy habitations, posessions and cultivations. There is a difference, however, between fire as an instrument of depradation or of scorched-earth tactics, and fire as a weapon - a means for exerting regulable force upon an enemy. Largely for technological reasons, the latter was long confined to specialized operations of siege and naval warfare. In such contexts, the documented history of incendiary warfare stretches back for some three millenia. Assyrian bas-reliefs have been found, for example, which show the defenders of a city besieged in the ninth century B.C. repelling siege engines by throwing burning liquid over them. The classic examples of naval fire weapons are the "fire-ship", such as those described by Thucydides, which were set adrift against enemy fleets or harbours, and the "Greek fire" of the Byzantines. The latter is perhaps the most renowned incendiary of antiquity. It was a petroleum-based liquid incendiary composition that came into prominence during the seventh century A.D. So far as can be judged from the frequently contradictory accounts, its revolutionary characteristics lay in the delivery means designed for it by the Syrian engineer and architect Callinicus, namely a high capacity pump that could be mounted in the bows of a warship or on the walls of a city.

144. The rise of artillery that followed the introduction of gunpowder brought with it certain new types of incendiary projectile, thus continuing a line of development that stretches back to the fire arrow. These new incendiary devices were soon eclipsed by explosive artillery shells, however, and it was not until the latter part of the eighteenth century that their use again became at all widespread. Like the fire arrow, they were primarily used to set fire to enemy fortresses or to destroy ships at sea.

145. As in so many other areas of military technology, rapid developments in incendiary weapons were made during the First World War. Although incendiary warfare techniques did not acquire much importance during the war, they were direct forerunners of those in use today.

146. The most portentous of the First World War techniques was the use of airships and aeroplanes to drop incendiary bombs on targets deep in the enemy rear or in the enemy homeland. Operations of this type were conducted by both sides. Their scale was relatively small in view of the limited capacity of contemporary aircraft. The total number of incendiary bombs to land on English towns, for example, was no more than about 3,000 (together with a larger number of high explosive bombs), but they caused considerable alarm among the civilian population.

147. Early in the First World War, the German Army introduced the flamethrower which it had been developing during the pre-war years. This heavy, immobile contrivance had much in common with the Greek fire syphon of Callinicus. It was used to project a blazing stream of oil at the strongpoint of the opposing trench system immediately before an infantry assault. In this role it occasionally achieved tactical success, and was copied by most of the other belligerents. Smaller, portable versions were also introduced. All in all, however, these weapons were too complicated, unreliable and dangerous to their users to be of much military value, and they were generally regarded as a failure.

148. Incendiary projectiles fired from artillery or trench-mortars were employed widely during the First World War. They were used in attempts to set fire to opposing trench systems or support facilities. They were also used as anti-personnel weapons: time fuses were fitted so that they detonated in the air, raining down a shower of burning phosphorus particles or molten iron (from thermite compositions). Hand grenades filled with white phosphorus or thermite were often used by raiding parties.

149. It seems that during the two decades after the First World War, weapons technologists and military theorists either lacked interest in incendiary weapons because of their inauspicious performance during the war, or were divided on their possible merit. For those who realized that air warfare, particularly against civilian targets, was likely to be of great importance in the future, the incendiary aircraft bomb seemed to have greater potentialities than other types of incendiary weapon. It was not obvious at that time, though, that incendiary bombs had any offensive superiority over high-explosive ones. In countries where tank development was being pursued enthusiastically, the armoured fighting vehicle was seen to some to have advanced the possibilities of flamethrowers,

for it might both increase their mobility and diminish the vulnerability of their operations. Mechanized flamethrowers mounted on combat vehicles were seen as a possible means for breaching the great defensive zones that were being built during these years, such as the Maginot Line. Likewise, it was also considered that emplaced flamethrowers might be valuable in the defence of such zones.

150. Several of these possibilities were put into practice during the 1930s. In the course of the Italo-Ethiopian War and the Spanish Civil War, portable and tank-mounted flamethrowers were used. So also were incendiary bombs in attacks on population centres. Similar techniques were employed in the Sino-Japanese conflict. These events stimulated wide military interest, and incendiary warfare development programmes were initiated or accelerated by all the major military Powers. By the time the Second World War broke out, many new weapons were available for battlefield trial.

Incendiary warfare against population centres and related targets

151. This section describes the use of incendiary weapons during and since the Second World War against civilians, against their natural environment and against their means of production and subsistence. The battlefield use of incendiary weapons is described in a later section. It should be noted at the outset that the distinction between these two sections is by no means clear-cut. Combat between opposing armed forces rarely takes place in unpopulated areas; and battlefield operations are unlikely to leave the local civilian population unscathed. This is so whatever the weapons used, but when area weapons, such as certain napalm devices, are employed, the consequences become magnified. Notwithstanding its significance, the principle of the distinction between combatants and non-combatants is often not respected in the conduct of total war.

152. Local non-combatant populations are placed in particular jeopardy in conflicts where there are no sharply defined front lines. Under such circumstances, they face the added danger of being mistaken for combatants and actively sought out for direct attack. In the Viet-Nam war, for example, and no doubt also in other less closely-observed conflicts, isolated hutments have frequently been targetted for attack. The probability of error in distinguishing combatants from non-combatants under such circumstances, even where that is in fact possible, is increased by the speed with which decisions relating to the attack are made, and the remoteness of the attacker from the target. When weapons as destructive as the napalm fire-bomb are employed, whose indiscriminateness is regarded not as a disadvantage but as a tactical asset of area-effectiveness, non-combatants may suffer at least as much as combatants.

Incendiary air raids on cities

153. During the first year of the Second World War, the use of incendiary weapons was largely confined to the battlefield. However, in September 1940, an air attack on London that included the use of incendiary bombs began a process of escalation

that was to establish the incendiary air attack as the most devastating instrument of mass-destruction yet employed in warfare. At first the targets of these attacks were ostensibly military, but civilians working in or living around them inevitably suffered heavily from the extreme inaccuracies of the early bombing techniques. The immunity of non-combatants provided for by the international law of war was breached initially by accident (it might be argued), but later by design, the point soon being reached where enemy civilians became primary targets of strategic bombing campaigns. Incendiary weapons proved to be the most efficient instruments used.

154. Although incendiary weapons had been used in air attacks on cities before the Second World War, few people anticipated the scenes of utter devastation that followed their use during that war. Around 100,000 tons of bombs were dropped on 60 Japanese towns and cities, practically all of them incendiaries. Eighty per cent by weight of the incendiaries were napalm bombs, the remainder magnesium or thermate. The air raids killed 260,000 people and injured another 412,000. Nearly two and a quarter million homes were destroyed, and 9.2 million people left homeless. In Germany, 1.35 million tons of bombs were dropped on population centres, 49 towns and cities being singled out for large-scale attack. Although less than a quarter of the bombs were incendiaries, more than three quarters of the resultant civilian casualties were due to fire. There are estimated to have been 1.4 million civilian air-raid casualties in Germany, of whom 600,000 died. Civilian air-raid casualties in the United Kingdom amounted to 147,000, including 61,000 dead.

155. During the earlier years of the Second World War, high-explosive bombs were believed superior to incendiaries for urban-area attacks. Analysis of reconnaissance photographs and other methods of evaluation, eventually demonstrated that this was not so. Incendiaries were then used on a rapidly increasing scale. After the war, it was calculated on the basis of observations made in Germany that, as regards material damage, one ton of incendiaries was equivalent to 4.8 tons of high-explosive bombs. 14/ Likewise, in Japan it was found that incendiaries had been twelve times as destructive as high-explosive bombs against readily-combustible targets, and 1.5 times as effective against fire-resistant targets.

156. The air raids that caused the greatest devastation in Germany during the Second World War were those directed against Hamburg in the summer of 1943 and against Dresden in February 1945. Both of them involved huge tonnages of incendiary weapons, and both succeeded in creating fire-storms. The number of dead was enormous, but in neither case are reliable statistics available. Around 135,000 people are believed to have been killed during the attack on Dresden, although both higher and lower figures have also been quoted. 15/ The town was swollen with refugees, the presence of a great many of whom was unrecorded, and in several areas all that remained of the inhabitants were heaps of corpses charred beyond all

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14/ H. Bond (ed.), Fire and the Air War (Boston, 1946).

15/ D. Irving, The Destruction of Dresden (London, 1963).

recognition and often into a state of complete disintegration. On 13-14 February 1945, 3,750 tons of bombs were dropped on the city, at least two thirds of them being incendiaries.

157. The attack on Hamburg was conducted intermittently but intensively between the nights of 24-25 July and 2-3 August 1943. The town was hit by 4,400 tons of high-explosive bombs, 2,700 tons of magnesium/thermite incendiaries and 1,900 tons of thickened-gasoline bombs. Some 3,000 bomber-aircraft missions were flown over the city, with 100,000 people mobilized to supply and conduct them. Most of the attacks were delivered under perfect bombing conditions against an enemy whose radar alert system had been jammed beforehand, and whose ground and air defences proved unusually ineffective. The weather was hot and dry. The first attack breached several major water-mains so that then and subsequently there was little hope of effective fire-fighting. The intensity and co-ordination of the attack on the night of 27-28 July were sufficient to build up a huge conflagration that in turn developed into a cyclone-like fire-storm. The asphalt of the streets burned. About half of the town-dwellings were totally destroyed, and only 20 per cent of the remainder were left undamaged. The area of destruction stretched over about 35 km^2 of the town centre, and left 40 million tons of rubble to be cleared away. Probably 43,000 or more people were killed, and it took more than two months to dig their corpses out of the debris.

158. The attack on Tokyo on the night of 9-10 March 1945 was conducted entirely with incendiaries. In terms of the number of dead, it exceeded in destructiveness either of the subsequent nuclear attacks on Hiroshima and Nagasaki. From 279 heavy bombers 1,665 tons of napalm bombs, most of them clusters of small 6-pound base-ejection devices, were dropped. Within half an hour, fire had taken hold of the readily-inflammable city centre and, fanned by a high wind, this built up into a huge conflagration that eventually destroyed or seriously damaged about 60 km^2 of Tokyo. The blaze could be seen from 40 miles away. Some of the modern fire-resistant structures in the middle of the city were not completely destroyed, but the majority even of these were left as sagging skeletons. Concrete, glass and steel bars melted in the intense heat, and wooden buildings went up in flames before the fire front had actually reached them. Some of the inhabitants were able to escape through the wide fire-lanes, but many others were encircled by the flames and died of suffocation and burns. Those who fled to the city canals faced death from the scalding water or from the stampeding mob crowding in and crushing on top of them. It is estimated that 83,800 people died and 41,000 more were injured. More than a million were left homeless.

159. Since the Second World War, incendiary air attacks against population centres have continued to be practised. One major example occurred during the Korean war, when a large part of the city of Pyongyang was destroyed by incendiaries in January 1951.

Use of incendiary weapons against environmental targets

160. Since the time of the First World War, there has been recurrent military interest in the use of incendiary weapons to harm the enemy through destruction

of his agriculture or rural environment. Harvests and crop cultivations have been one objective, in strategies of attrition or food denial. Tracts of natural vegetation have been another, the aim being to facilitate aerial reconnaissance or target acquisition, or to reduce the attractions of particular areas of countryside as locations for base camps, groupment areas or supply zones. Regular fire weapons often being unsuited for these purposes, special weapons and techniques have been developed and used instead. Except on a small scale, these attempts have not been notably successful, but it is conceivable that in some parts of the world they might become more so in the future.

161. Leaflet incendiaries (see paragraph 51) and related weapons were dropped in substantial numbers over German grain-fields during the early part of the Second World War.

162. During 1965-67, attempts were made in Viet-Nam to initiate mass-fires in forest areas. 16/ The sites were ones where the jungle canopy had previously been desiccated with anti-plant chemical warfare agents. Large numbers of incendiaries were used, but mass fires did not develop, although substantial local damage resulted from at least one of them. Even though the attacks were delivered during the dry season, the vegetation was apparently too damp to carry the fire. It would be wrong to assume, however, that heavy use of incendiary weapons cannot cause substantial local fires in forest or other rural areas, even though mass-fires may not develop. In one interdiction operation conducted in Viet-Nam with large numbers of incendiary bombs, for example, some tens of square kilometres of forest are reported to have been destroyed. 17/

Incendiary warfare on the battlefield

163. Outside the Pacific theatre, battlefield incendiary weapons did not become prominent during the Second World War. Emplaced flamethrowers and flame fougasses 18/ were sometimes incorporated into fortified defensive positions, for example around Moscow and the south-east coast of England. Both portable and mechanized flamethrowers of various types and sizes were available to the belligerent armies but were used only occasionally. In the Pacific campaigns, however, incendiary weapons came to be used extensively on the battlefield after they had been found especially well suited to the nature of the ground fighting and the terrain over which it was conducted. The availability of napalm-soap thickened fuels from the summer of 1943 onwards provided another stimulus, for

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16/ D. Shapley, "Technology in Viet-Nam: Firestorm project fizzled out", Science, 177:239-241, 1972.

17/ K. Hartmann, "Chemische Kriegführung 1966-67", Wehrkunde, N.7, 341-343, 1967.

18/ Flame fougasses are emplaced devices that are capable of projecting a mass of burning incendiary agent over the surrounding area when they are activated by a trip wire or by remote control.

their superiority over other fuels greatly increased the capabilities of flamethrowers. Thickened gasoline compositions formed the basis for a novel aircraft incendiary weapon that proved notably effective in ground-support operations. This was the "fire-bomb" (see paragraph 44) initially improvised from auxiliary aircraft fuel-tanks filled with gasoline or oil.

164. Compared with conventional ground weapons, the tonnage of napalm weapons used during the Second World War was small. This situation changed during the Korean war, when napalm began to acquire its present reputation as a militarily effective weapon. One of its users described it as the "best all around weapon in Korea". The total consumption during the war was 32,315 tons. Several armed services around the world subsequently adopted napalm, and it has apparently been employed almost as a matter of course in a number of recent conflicts. Its widest use has been in Viet-Nam, where seven months of fire-bombing during 1966 spread as much napalm as had been used during the entire Korean war, with still greater quantities being used subsequently. By March 1968 the total consumption is reported to have been well over 100,000 tons. 19/ Most of it appears to have been used in air weapons, for as will become apparent, these have a wider range of applications than napalm ground weapons.

165. The other main battlefield incendiary weapons of present-day warfare are based on white phosphorus. As noted in chapter I, this material can serve a triple military function: as a smoke agent for screening purposes; as an incendiary agent for setting fire to readily combustible matériel; and as an anti-personnel agent. For each of these roles, more efficient agents are available, but there is none that combines all three. It continues to be used in large quantities.

Battlefield use of napalm ground weapons

166. In the hands of ground forces, napalm has on occasion been used effectively in defensive operations, but it is primarily a special-purpose assault weapon for the destruction of enemy soldiers holding positions that are protected against explosives, bullets or shrapnel. Flamethrowers, both portable and mechanized, are the principal weapons here, for they can project lethal streams of flame over obstacles, around corners, and into narrow openings. They can sometimes be used on rugged terrain and, in particular, have proved efficacious when other weapons have failed in dislodging defenders from tenaciously held positions such as pill-boxes and certain types of cave defence.

167. Flamethrowers are also used to attack areas containing concealed positions whose precise location is unknown. Sprayed with napalm, the concealing cover may be burnt away and the defenders killed or put out of action while the attacking forces advance.

19/ J. B. Neilands, "Vietnam: Progress of the chemical war", Asian Survey 10(3) 209, 1970.

168. The military use of portable flamethrowers is limited primarily to street or jungle fighting. In other situations they have too many operational limitations. They range is much shorter than that of small-arms fire so that their use may not be feasible unless there is plenty of cover and supporting fire. Their use against fortified positions commanding long, inter-locking fields of fire may never be feasible. Their fuel capacity is limited, and because flamethrower operations may fail unless the objective is completely saturated with flame, several flamethrowers may have to be employed at once. The co-ordination required between the different operating crews, and between them and their fire-support units, increase the complexity of the operation and reduce the number of occasions on which it may be worthwhile. Mechanized flamethrowers have similar military limitations.

169. Other offensive applications for flamethrowers include the destruction of small pockets of organized resistance left behind or circumvented during a rapid advance, for these will often be deprived of covering fire. Flamethrowers have also been used on patrols and marches to reconnoitre suspected ambush positions. Their drawbacks here, however, are their weight, in the case of the portable ones, and their limited capacity.

170. When napalm is effective, its effectiveness may stem both from its fierce casualty-producing properties and from its psychological impact. In the view of a current military manual on napalm weapons, the latter may often be the more important. Man seems to have an intense inbred fear of fire, and napalm weapons may unnerve him to an extent which other forms of attack may not. There are several recorded instances where troops seasoned to heavy artillery bombardment have broken and fled when attacked with napalm, and it is said that more prisoners tend to be taken in operations where it is used. Instances are also recorded where soldiers facing advancing flamethrowers have committed suicide inside their bunkers.

171. On the defensive, the area-effectiveness and psychological impact of napalm have proved successful in blunting or breaking up massed infantry assaults. Napalm land mines or improvised fougasses have successfully been used along defensive perimetres. Here they have several roles. The functioning of booby-trap devices may secure enemy casualties and provide an obvious warning of enemy approach, and illumination during periods of low visibility. Their psychological effects may deter or demoralize an enemy advance. They may be used like conventional mines to block avenues of approach that cannot be covered by direct-fire weapons.

Battlefield use of napalm air weapons

172. The fire-bomb is the principal napalm air-support weapon. A thousand or more square metres of ground around its point of impact become splattered with blazing napalm, which creates a huge wall of rolling fire that burns for several minutes, the flames often reaching high above tree-top level. Its destructiveness and psychological impact are therefore great.

173. The fire-bomb originally gained much of its reputation among field commanders as an anti-matériel weapon, particularly against tanks and heavily dug-in

emplacements. It continues to be used in these roles, and also against such targets as convoys of supply vehicles, structures containing command posts, and anti-aircraft missile emplacements. The area of effectiveness of a fire-bomb is often greater than that of a high-explosive weapon of the same size, and direct hits may therefore be less necessary. The napalm may spread over an area larger than that which would be damaged by an explosive burst, and it may initiate a secondary fire that spreads still further. Its intense heat of combustion may buckle or melt non-inflammable structures such as weapon components or other machinery, and, as explained in paragraph 96, cause internal-combustion engines to break down.

174. The fire-bomb is also an anti-personnel weapon, and because of its area-effectiveness, it has proved an exceedingly efficient one. People caught in the open by an aircraft coming in low and fast with fire-bombs have little chance of escape. Natural cover may not offer much protection. Although it may reduce the bomb-aimer's accuracy, the area-effectiveness of the weapon may compensate for this, particularly if several are dropped. Natural cover may in fact increase people's vulnerability because it may promote the spread of secondary fires.

175. Ground-support aircraft are becoming the dominant weapon in operations against guerrilla units or against other isolated units operating in remote areas. Anti-personnel weapons are often their principal armament. In one much-used technique, ground patrols in an area withdraw as soon as they locate enemy units, and call in ground-support aircraft to saturate the area with anti-personnel munitions. The fire-bomb is often preferred for the purpose. In another type of operation, the ground units are dispensed with altogether and strike aircraft laden with fire-bombs or similar ordnance rove over territory believed to contain enemy personnel, searching for "targets of opportunity". This technique, which has been extensively employed in several parts of the world, allows little opportunity for verifying that the people who are to come under attack are in fact enemy personnel, and not non-combatant local inhabitants.

Social and economic consequences of incendiary warfare

176. The experience of the past has demonstrated that incendiaries are among the most powerful means of destruction and devastation. This is most evident in cases where they are massively employed against urban targets. Except for nuclear weapons, and perhaps also certain biological and chemical weapons, no other armament places such destructive power in the hands of military commanders. Even when they are used as individual weapons, they may still strike over a considerable area, or initiate fires that spread far beyond their immediate targets. The element of control which can be exercised over the effects of such weapons as bullets, or even high explosive bombs, is lacking in the case of most incendiary weapons, and like all area weapons they are essentially indiscriminate. They may bring uncontrollable destruction to the lives, possessions and habitations of combatants and non-combatants alike. These and related aspects are assessed in the following paragraphs in relation to their major social and economic consequences.

177. Incendiary weapons, when used in massive raids against urban targets, demonstrate the total quality of war: its savage and cruel consequences for all of society. This characteristic is shared with other weapons that are adaptable to mass destruction, but incendiaries have, in certain circumstances, proved particularly destructive. As noted in paragraph 155 above, when comparisons were made between the effects of equal weights of incendiaries and of high explosives directed against urban targets, it was found after the Second World War that on average incendiaries had been some four or five times more destructive. They affected wider areas over a longer time period and presented greater difficulties to the defensive rescue efforts. Although comparisons of this type do not permit generalizations about the relative importance of different kinds of weapons, the example quoted undoubtedly suggests that incendiary weapons are among the most powerful means known for causing mass destruction in urban areas. Any attempt to reduce the catastrophic social and economic consequences of total war should therefore have as a major objective the prevention of the massive use of incendiaries.

178. The use of incendiary weapons on the scale of the major incendiary air raids of the Second World War is, in economic terms, an extremely costly undertaking. Three quarters or more of the physical destruction wrought by bomber aircraft in Germany during the Second World War was due to fire, and it was estimated after the war that each square mile of destruction had cost between 10 and 35 million dollars in terms of aircraft, ordnance and equipment expended. The poorer nations of the world are therefore more likely to be the recipients of such attacks than the executors, and may suffer irremediable economic hardship from their consequences.

179. Concerning other modes of incendiary warfare, the economic perspective may be rather different. The great costs of the large-scale incendiary attacks of the Second World War stemmed from the delivery systems used - complex bomber aircraft - and their heavy losses in the face of sophisticated air defences. In other conflict situations, where the objectives are less ambitious, or where the air defences are weaker or non-existent, relatively small numbers of less sophisticated aircraft, perhaps even modified civil aircraft, may provide an effective delivery means. Under such circumstances, the relatively low costs of the incendiary weapons themselves could become a significant factor. As described in chapter I, some incendiary agents, napalm in particular, are exceptionally cheap and easily produced, even in the less developed countries. It is thus possible to conceive of situations in which incendiary weapons could permit warring countries that do not posess substantial military or economic resources to inflict exceptionally severe damage upon one another.

180. The tactical employment of air-delivered fire-bombs is an important aspect of the use of napalm in particular. It is a tactic, however, that often demonstrates the indiscriminate nature of incendiary warfare against a society. Because of the considerable area covered by each napalm bomb and often great inaccuracy of its delivery, and because also of the frequently close proximity of military and civilian objects, fire-bombs may cause severe damage in the civilian sector even when, ostensibly, the targets of attack are military. This may have far-reaching

social and economic consequences, for example in terms of voluntary or forced evacuation or movement of civilians from areas of strife. Similarly, there may be instances where incendiary ground weapons, notably flamethrower-employment in street fighting, may be used by the military in such a way that considerable civilian casualties result, again drawing attention to the indistriminate nature of napalm and other incendiary weapons.

181. In some circumstances, napalm and other incendiary weapons may be used to destroy forests, crops and other vegetation. In the short run, such attacks may affect the supply of food to the population concerned, creating hazards of malnutrition and, in severe cases, of starvation that often will present the greatest threat to the lives of the old and the very young. Such attacks may also be intended to damage the supply of certain raw materials, such as wood, pulp and rubber. Should they succeed, many years may elapse before the afflicted areas regain their productivity. Moreover, it is known that the burning of a forest may have drastic long-term consequences, some of which may be irreversible. Erosion may set in more readily in an area denuded of vegetation. The run-off of rain water increases, which may lead to a gradual lowering of the water table. This in turn may have wider hydrological and meteorological effects which may provide adverse conditions for the re-establishment of the original flora and fauna of the area. Little is known of these long-term effects of widespread fire. This, however, is not a valid reason for disregarding them. It is instead a reason for expressing alarm concerning the use of incendiary weapons against man's rural environment.

182. It is important to recognize that the care and treatment of burn casualties represents a more difficult problem for hospitals than the treatment of most other kinds of casualty. The resources and manpower needed for treating large numbers of casualties have been described in chapter III. It is clear that it would be next to impossible even for a highly developed country to mobilize the necessary resources to treat the casualties caused by massive use of incendiaries. Conditions would be even more difficult in less developed countries, resulting in a situation where large numbers of people suffering from severe pain would have to be left without care.

183. The possibilities of providing protection for the civilian population against the effects of incendiaries are not very promising, especially when the effects of mass fire in urban areas are considered. Although it is possible to conceive of a shelter programme of sufficient quality to enable a city population to survive a conflagration or even a fire storm, such a programme would be very expensive, both economically and in terms of changes in the society, and would take many years to establish. Few if any countries have undertaken such a programme. Against less serious fire situations, protective measures become more feasible, but there are few towns in the world today which would escape serious damage even from this menace. In situations where incendiaries are used tactically, the local non-combatants are, as a rule, much more vulnerable than the combatants, who are familiar with the destructive properties of incendiary weapons, and trained in the various countermeasures. The indiscriminate nature of the effects of incendiary weapons is thus further underlined by the difficulties of providing adequate protection for the civilian population.

CHAPTER V

CONCLUSIONS

184. There exists today a broad range of incendiary weapons designed for use both on the battlefield and against population centres and other vital targets. Many of these weapons are extremely simple to manufacture, and the necessary raw materials are readily available the world over. This is particularly true of napalm weapons, which are already a part of the arsenals of a number of countries. The development continues towards incendiary weapons of still greater destructiveness, and there may also follow a proliferation of these weapons throughout an increasing number of States. The situation is therefore gradually deteriorating and this underlines the urgent need for international consideration of effective measures of disarmament concerning incendiary weapons.

185. Massive use of incendiary weapons creates fires that may merge and grow into widespread conflagrations and fire storms. Such mass fires are largely uncontrollable and usually present insurmountable difficulties for the protection of civilians and the environment in which they live. It follows from this, and from past wartime experience, that incendiaries are among the most powerful means of destruction in existence; they characterize the savage and cruel consequences of total war. Any attempt to constrain the conduct of total war should therefore include the elimination of the use of incendiaries on a massive scale.

186. The massive spread of fire is largely indiscriminate in its effects. When there is a difference between the susceptibility to fire of military and civilian targets, it is commonly to the detriment of the latter. The same applies to certain tactical applications of incendiaries, for the ability of these weapons to strike over an appreciable area, and the often close proximity of military and civilian targets, may also have consequences that are essentially indiscriminate.

187. Burn injuries, whether sustained directly from the action of incendiaries or as a result of fires initiated by them, are intensely painful and, compared with the injuries caused by most other categories of weapon, require exceptional resources for their medical treatment. Under war conditions only a few of the people exposed to more extensive napalm burns survive to the period of real convalescence, which is long and difficult. Permanent loss of function, disfigurements and severe scarring are frequent. Disabilities, impairment of sight or hearing, and grave emotional disorders are often the consequences of this. Plastic repair and reconstruction of the damage is very difficult and painful, and may have only limited effect. When judged against what is required to put a soldier out of military action, much of the injury caused by incendiary weapons is therefore likely to be superfluous. In terms of damage to the civilian population, incendiaries are particularly cruel in their effects.

188. Napalm and other incendiary weapons owe their effect not only to heat and flame, but also to the toxic effects of carbon monoxide and other combustion products. This is true particularly for people sheltering in confined spaces, but may also be significant when they are in the open. Asphyxiating effects may also be

important, particularly in connexion with the massive use of incendiaries. Here it is the action of dense smoke and the depletion, through fire, of atmospheric oxygen that are primarily responsible. The toxicity of white phosphorus may also be an important consideration for the injuries sustained from weapons utilizing this material. Napalm weapons often contain white phosphorus, and this may further aggravate the burn injuries they cause.

189. Attempts have been made to use incendiaries to damage crops, forests and other features of the rural environment. Although there is a lack of knowledge of the effects of widespread fire in these circumstances, such attempts may lead to irreversible ecological changes having grave long-term consequences out of all proportion to the effects originally sought. This menace, though largely unpredictable in its gravity, is reason for expressing alarm concerning the massive employment of incendiaries against the rural environment.

190. The rapid increase in the military use of incendiary weapons, especially napalm, during the past 30 years is but one aspect of the more general phenomenon of the increasing mobilization of science and technology for war purposes. New weapons of increased destructiveness are emerging from the research and development programmes at an increasing rate, alongside which the long upheld principle of the immunity of the non-combatant appears to be receding from the military consciousness. These trends have very grave implications for the world community, which, through the widespread deployment of nuclear weapons, already has the possibility of complete destruction poised over it. It is therefore essential that the principle of restraint in the conduct of military operations, and in the selection and use of weapons, be researched with vigour. Clear lines must be drawn between what is permissible in time of war and what is not permissible. Incendiary weapons, in particular napalm, are already the subject of widespread revulsion and anxiety, and because they are weapons of great destructive potency, they are a fitting subject for renewed efforts of this type.

191. The law of armed conflict is the formal expression of the principle of restraint. There exist well-established juridical norms that have a bearing on incendiary warfare in view of the properties of incendiary weapons as set forth in the present report. These provisions require close study with a view to further improvement.

192. Most of the norms referred to in the previous paragraph are embodied in the Hague Regulations of 1907, particularly articles 22 20/ and 23 (e) 21/ which, according to many experts, have become part of customary international law. The principle of a distinction between military targets and civilian population also occurs in the body of international customary law. Attention may be drawn, for

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20/ Article 22 states that "The right of belligerents to adopt means of injuring the enemy is not unlimited".

21/ Article 23 (e) states that it is forbidden "to employ arms, projectiles, or material calculated to cause unnecessary suffering".

example, to the 1923 draft rules relating to aerial warfare. 22/ The principle of the immunity of the non-combatant has been reaffirmed since then, notably by the United Nations General Assembly (resolutions 2444 (XXIII) and 2675 (XXV)) and by an International Conference of the Red Cross (XX International Conference, Vienna, 1965, resolution XXVIII). The principle is also to be embodied in the draft Additional Protocol(s) to the Geneva Conventions of 1949 being prepared by the International Committee of the Red Cross. Also requiring consideration in view of the toxic and asphyxiating effects of many incendiaries, is the 1925 Geneva Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare.

193. It is not the purpose of this report to assess the use of incendiary weapons in the light of legal and humanitarian principles. Nevertheless, in view of the facts presented in the report, the group of consultant experts wishes to bring to the attention of the General Assembly the necessity of working out measures for the prohibition of the use, production, development and stockpiling of napalm and other incendiary weapons.

22/ Article 22 states that "Air bombardment for the purpose of terrorizing the civil population, of destroying or damaging private property not of military character or of injuring non-combatants is prohibited".

Properties of selected incendiary agents

Agent	Examples of typical formulations	Appearance	Approximate heat of combustion (cal/cm^3)	Approximate maximum burning temperature in air (degree C)	Types of munition in which used	Cost[a/] of a typical munition charged with the agent. (Unit of cost is a 107-mm high-explosive mortar projectile)
Metal incendiaries						
Magnesium	Alloy containing 86% magnesium, 13% aluminium and 1% copper	Light white metal	11,000	2,000	Aircraft bomblets	
Pyrotechnic incendiaries						
Thermite	27% aluminium granules, 73% ferrosoferric oxide	Grey-black powder	3,400	2,400	Magnesium or thermate munitions	
Thermate	60% thermite, 25% barium nitrate, 5% aluminium filings, 10% binder	Compressed dark-coloured powder			Aircraft bomblets; hand-grenades	350-kg cluster of magnesium-alloy/thermate bomblets; 58 b/
Pyrophoric incendiaries						
White phosphorus	White phosphorus	Waxy yellowish solid	10,600	1,200	Grenades; mortar and artillery projectiles; small rockets; land mines; aircraft bombs and bomblets	105-mm artillery shell: 1.5 c/ 70-mm air-to-ground rocket: 1.7 50-kg aircraft bomb: 5.9
Plasticized white phosphorus	Finely divided white phosphorus suspended in a rubber-xylene gel	White rubbery solid				
	Triethyl aluminium thickened with poly (isobutylene)	Pale-coloured syrup	13,000	2,000	Small rockets	66-mm rocket for portable multibarrelled launcher: 1.3
Oil-based incendiaries						
Pyrogel	30% gasoline thickened with 3% IM* and mixed with 49% goop**, 10% magnesium and 5% sodium nitrate	Black sticky almost solid composition	8,000		Aircraft bombs and bomblets	
Pyrogel	60% gasoline thickened with 5% polybutadiene and mixed with 28% magnesium, 6% sodium nitrate and a trace of p-aminophenol	Light sticky almost solid composition		1,200-1,600	Aircraft bombs and bomblets	

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Properties of selected incendiary agents (continued)

Agent	Examples of typical formulations	Appearance	Approximate heat of combustion (cal/cm^3)	Approximate maximum burning temperature in air (degree C)	Types of munition in which used	Cost[a/] of a typical munition charged with the agent. (Unit of cost is a 107-mm high-explosive mortar projectile)
Oil-based incendiaries (continued)						
Napalm	Gasoline thickened with 10-20% of a mixture of IM,* stearic acid and calcium oxide	Pale-coloured jelly	10,000		Aircraft bombs and bomblets	
Napalm	Gasoline thickened with 5-10% of aluminium soaps of naphthenic, oleic and coconut acids	Sticky brownish syrup or jelly	10,000	800-1,200	Aircraft bombs and bomblets; flamethrowers; land mines	
Napalm	Gasoline thickened with 2-5% of diacid aluminium soaps of iso-octanoic acids	Translucent syrup or jelly	10,000		Flamethrowers; land mines	
Napalm	25% gasoline, 25% benzene and 50% of a polystyrene	Sticky brownish syrup or jelly			Aircraft bombs	350-kg fire-bomb: 6.9 b/

* A polymer of iso-butyl mathacrylate.

** Goop is a name given to the input composition for the Hanagirg magnesium process, namely a paste of magnesium oxide, carbon, asphalt and oil.

a/ Based on current procurement costs in an advanced industrialized country. The procurement costs for incendiary-agent ingredients, in units of the cost of an equal weight of the high-explosive TNT (Trinitrotoluene), are roughly as follows: magnesium metal, 1.4; white phosphorus, 0.8; and gasoline, 0.08. According to their composition, napalm range in cost from less than 0.4 to more than 4 of these TNT units. For comparison, it may be noted that the nerve gas sarin, and the tear gas CS, each cost about 10 times as much as TNT.

b/ For comparison, it may be noted that a 350-kg "general purpose" demolition bomb charged with high explosive costs about nine of these mortar-projectile units.

c/ For comparison, it may be noted that the costs, in mortar-projectile units, of other types of 105-mm artillery shell are as follows: high explosive, 1.1; illuminating, 2.1; depleted-uranium flechette, 7.2.

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