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Parameters for Estimation of Casualties from First and Third Degree Flash Burns

Carl A. Curling
Samantha Todd

March 2017
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IDA Paper P-8374
Log: H 17-000154

INSTITUTE FOR DEFENSE ANALYSES
4850 Mark Center Drive
Alexandria, Virginia 22311-1882

About This Publication

This work was conducted by the Institute for Defense Analyses (IDA) under contract HQ0034-14-D-0001, project CA-6-3079, "CBRN Casualty Estimation and Support to the Medical CBRN Defense Planning & Response Project," for the Joint Staff, Joint Requirements Office (JRO) for Chemical, Biological, Radiological and Nuclear (CBRN) Defense (J-8/JRO) and the US Army Office of The Surgeon General (OTSG). The views, opinions, and findings should not be construed as representing the official position of either the Department of Defense or the sponsoring organization.

Acknowledgments

The authors are grateful to Mr. James M. Demyanovich and Dr. Katherine M. Sixt for their careful and thoughtful review of this document, to Ms. Dana Coppola for editing, and to Ms. Amberlee Mabe-Stanberry for producing this document.

For More Information:

Dr. Carl A. Curling, Project Leader
ccurling@ida.org, 703-578-2814
Mr. Michael L. Dominguez, Director, Strategy, Forces and Resources Division
mdomingu@ida.org, 703-845-2527

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Executive Summary

At the request of the Office of the Surgeon General (OTSG), the Institute for Defense Analyses (IDA) previously adapted an existing symptom-based methodology to estimate the number, type, and timing of chemical, biological, radiological, and nuclear (CBRN) casualties. The result of that effort is now promulgated as North Atlantic Treaty Organization (NATO) Standardization Agreement (STANAG) 2553, *Allied Medical Publication 8, NATO Planning Guide for the Estimation of CBRN Casualties* (*AMedP-8(C)*). Since the promulgation of *AMedP-8(C)*, IDA has performed additional analyses to extend the capabilities of the *AMedP-8(C)* casualty estimation methodology, including additional biological agents and models to incorporate the effects of medical treatment on the casualty estimate.

This document describes the continued extension of the methodology to include 1st and 3rd degree flash burns – 2nd degree flash burns are already included and constitute the primary injury mechanism from exposure to the thermal component of nuclear weapon effects. The document supports transparency, reproducibility, and potential future refinement of the models by detailing the analytical choices made when determining parameters. The intent is that the new models will be considered for inclusion in the next edition of *Allied Medical Publication 7.5* (*AMedP-7.5(B)*). The first edition of *AMedP-7.5* (*AMedP-7.5*(A)) is currently in distribution as a Ratification Draft within NATO, and will eventually replace *AMedP-8(C)* in NATO doctrine. Because the new models will be considered for *AMedP-7.5*, they are designed to fit with it, rather than with *AMedP-8(C)*.

Flash burns result from the initial thermal pulse from a nuclear weapon detonation. The thermal pulse from a detonation lasts from a fraction of a second to several seconds (increasing with yield), and is assumed to result in exposure to the skin on the body (typically not more than 50% of the total body surface area (50% TBSA)). This analysis will not address burns from fires secondary to the thermal pulse, and will not address optical burns (flash blindness or retinal burns). These are also not addressed as casualty mechanisms in the NATO CBRN casualty estimation methodology.

In addition to not considering 1st and 3rd degree flash burns, there is one prominent aspect of casualties from flash burns in conjunction with other injuries from nuclear weapons that is not considered in the NATO CBRN casualty estimation methodology: “combined injuries.” In this context, combined injuries are those that occur from multiple injury mechanisms at once: flash burns combined with radiation, radiation combined with blast injuries, blast injuries combined with flash burns, or all three mechanisms acting

simultaneously. There is some research indicating that the combination of flash burns with radiation, or blast injuries with radiation, could result in casualties (including fatalities) at insult levels well below what might normally be regarded as significant.[1] In the NATO casualty estimation methodology, however, the decision was made not to consider this aspect of combined injuries. This was based on the judgment that, "There are … very little data available on combined injuries. Thus, creating a model of such injuries is not feasible, and each injury is therefore treated separately, as if there is no synergy between the different types of injury."[2]

Summary of Proposed Models

This analysis identified the threshold fluence values (Q_t) for 1st and 3rd degree burns to bare skin and various uniform types. These are parameters currently not considered in the NATO CBRN casualty estimation methodology and are necessary to estimate the fraction of the total body surface area (% TBSA) of those burns for personnel in the vicinity of a nuclear weapon. This analysis reviewed the documents cited in the development of the NATO CBRN casualty estimation methodology to determine the threshold fluence values to include for consideration of 1st and 3rd degree burns. The most significant aspect of the definition of Q_t was the specification of a fixed ratio of these values of 0.8 for 1st:2nd degree burns, and 1.53 for 3rd:2nd degree burns.

Thermal Fluence Threshold (Q_t) Values for Various Burns and Uniform Types

Uniform/Clothing	1st Degree Burns [Cal/cm2]	1st Degree Burns [kJ/m2]	2nd Degree Burns [Cal/cm2]	2nd Degree Burns [kJ/m2]	3rd Degree Burns [Cal/cm2]	3rd Degree Burns [kJ/m2]
Bare Skin	2.08	87.2	2.61	109	3.98	167
Battledress Uniform (BDU) + T-shirt	5.93	248	7.41	310	11.3	474
BDU + T-shirt + Airspace†	12.0	504	15.1	630	23.0	963
Battledress Overgarment (BDO)	8.03	336	10.0	420	15.3	642
BDO + Airspace†	12.8	536	16.0	670	24.5	1,020
BDO + BDU + T-shirt	24.9	1,040	31.1	1,300	47.5	1,990
BDO + BDU + T-shirt + Airspace†	38.4	1,610	48.0	2,010	73.5	3,070

† Airspace indicates looser clothing (i.e., clothing with airspace between the body and the garment), as opposed to fitted clothing.[3]

A second aspect of the NATO CBRN casualty estimation methodology is the characterization of injuries, such as a burn, by severity over time as a function of the insult

[1] Palmer, Jessica L. et al. "Development of a Combined Radiation and Burn Injury Model." *Journal of Burn Care and Research*, official publication of the American Burn Association, 32.2 (2011): 317–323. PMC. Web. 23 Feb. 2017, 4.

[2] *AMedP-7.5* TRM, 14-2.

[3] *AMedP-7.5* FD, Note to Table 4-59, 4-70

range. Flash burns on a nuclear battlefield do not happen independently, and a 2nd or 3rd degree burn will not usually occur without surrounding tissue experiencing a more minor burn. An extensive 1st degree flash burn, at greater than 10% TBSA, will also include within the burn area at least a 1% TBSA 2nd degree burn, and would be a more severe injury than just a superficial burn. The 1st degree burn insult range is, therefore, 1–<10% TBSA. For 1st degree burns in the insult range of 1–<10% TBSA, the injury severity was found to be relatively minor, fitting within the definition of "Severity Level 1 (Mild)," and lasting for no more than a week without treatment. (Note that severity levels range from "Severity Level 0 (No Observable Injury) to Severity Level 4 (Very Severe).)

1st Degree Burn Injury Profiles

Time Point (hr)	Insult Range 1 – < 10 %BSA
0.1	1
24	1
48	1
336	0

Characterization of the injuries associated with 3rd degree burns was more complex. These are more severe burns that involve more organ systems in the body, and 3rd degree flash burns do not occur in the absence of 2nd degree burns (and probably 1st degree burns, as well). This analysis found that there was a more narrow set of insult ranges for 3rd degree burns than for 2nd degree burns, but that this more narrow range was encompassed by the already identified 2nd degree burn insult range. This resulted in essentially no change in the characterization of burns, by severity over time, when considering both 2nd and 3rd degree burns. Since the NATO CBRN casualty estimation methodology already assumes both types of burns to occur simultaneously, there was no change in the injury severity over time for untreated 2nd and 3rd degree burns in the NATO CBRN casualty estimation methodology.

3rd Degree Burn Injury Profiles

Time Point (hr)	Insult Range		
	1 – < 5 %BSA	5 – < 20 %BSA	≥ 20 %BSA
0.1	2	3	3
24	2	3	4[a]
48	2	3	
336	2	3	

[a] Death is modeled to occur at this point, based on the default value of the parameter $T_{death\text{-}CN\text{-}SL4}$ in *AMedP-7.5*.

Source*: AMedP-7.5* FD, 1-14.

The final aspect of the NATO CBRN casualty estimation methodology is the consideration of the casualty status with medical treatment. 1st degree burns are routinely treated with "over the counter" medications to ease the pain and moisturize the skin. If this medical care is available on the battlefield (an assumption of the NATO CBRN casualty estimation methodology), the medical treatment outcome reporting table (MTOR) for 1st degree burns has the casualty returning to duty immediately following treatment. (Because of the reporting rules in the NATO CBRN casualty estimation methodology, this is reported on Day 2.)

1st Degree Burn Medical Treatment Outcome Reporting

Insult Range [%BSA]	DOW	CONV	RTD
1 – < 10	0%	0%	Day 2: 100%

For 3rd degree burns, because the NATO CBRN casualty estimation methodology already considers 2nd degree burns to include some extent of 3rd degree burns, there was very little change to the MTOR. A literature review did identify, however, the recommendation that, "Thermally injured patients are best moved during the first 48 hours after being injured …"[4] This would result in patients with greater than a 5% TBSA 3rd degree burn, or a 20% TBSA 2nd degree burn, becoming convalescent (CONV) (by evacuation to a burn center) at 48 hours. This is different from what is presented in the current NATO CBRN casualty estimation methodology. Note that this evacuation is done to a higher level medical facility tailored to provide care to burn patients. At this time, this does not result in any changes to the "Died of Wounds (DOW)" or "Returned to Duty (RTD)" estimates, whether for burn injuries or any other CBRN injury or insult.

Medical Treatment Outcome Reporting For 3rd Degree Burn in the Presence of 2nd Degree Burn

Insult Range [%BSA]				
2nd & 3rd Degree Burn	3rd Degree Burn ONLY	DOW[a]	CONV[b]	RTD
1 – < 10	1 – < 2.5	0%	0%	Day 15: 100%
10 – < 20	2.5 – < 5	0%	0%	Day 23: 100%
20 – < 30	5 – < 10	0%	Day 2: 50%	Day 33: 50%
30 – < 45	10 – < 20	Day 9: 30%	Day 2: 70%	0%
≥ 45	≥ 20	Day 9: 50%	Day 2: 50%	0%

[a]DOW casualties from burns occur after evacuation to the burn center.

[b]CONV occurs because of evacuation to a burn center.

[4] William G. Gioffi Jr., et al. "Chapter 11. The Management of Burn Injury," *Textbook of Military Medicine*, Falls Church, VA: Department of the Army, Office of the Surgeon General, Borden Institute, 1991: 11, 368.

At the end, this analysis uses an illustrative scenario to address the significance (or lack thereof) of considering 1st and 3rd degree flash burns in the casualty estimate. In this scenario, 1st degree burns did not occur in the insult range of 1–<10% TBSA because no individual was estimated to have been exposed in the appropriate thermal fluence range. Changing the time for CONV for casualties with greater than 20% TBSA burns (which include 3rd degree burns of 5% TBSA or greater), did shift 27 persons (out of 816) to CONV on Day 2 from Days 15-30.

The conclusion of this analysis results in three recommendations:

1. While the consideration of 1st degree burns may provide the commander and staff with an indication of the incidence of these burns, on the nuclear battlefield this injury is relatively minor and probably should not be considered significant.

2. 3rd degree burns are not minor, and the medical care requirement is not insignificant, but the expected incidence of 3rd degree burns is already considered in the estimation of burn casualties. It might be of interest to the medical planner to enumerate the number and severity of 3rd degree burns separately, and this analysis demonstrates that possibility, but it does not change the casualty estimate. There should not be a consideration of 3rd degree burns as a separate injury category.

3. The NATO CBRN casualty estimation methodology should be modified to specify CONV for all casualties with 20% TBSA or greater of 2nd degree burns, based on the recommendation to evacuate these casualties to a burn center. Unlike for other CBRN injuries, CONV in this case moves the patients to a higher-level medical facility. A determination is still to be made on whether the DOW or RTD estimates for burn injuries or other concurrent CBRN injury or insult should be included in the casualty estimate, as the DOW or RTD would occur out of theater.

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Contents

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1. Introduction

In 2013, the U.S. Army Office of the Surgeon General (OTSG) tasked the Institute for Defense Analyses (IDA) to "Describe the qualitative and quantitative human response parameters of 1st and 3rd degree flash burns resulting from a nuclear detonation, the appropriate medical response, and the impact of medical response on those human response parameters."[5] The objective of this study is to describe human response parameters for 1st and 3rd degree flash burns, which are not already addressed in the NATO CBRN casualty estimation methodology, as described in Allied Medical Publication 7.5, *NATO Planning Guide for the Estimation of CBRN Casualties*.[6] Flash burns result from the initial thermal pulse from a nuclear weapon detonation. The thermal pulse from a detonation lasts from a fraction of a second to several seconds (increasing with yield), and is assumed to result in exposure to the skin on the body (typically not more than 50% of the total body surface area (50% TBSA)). 1st degree burns are not included in the NATO CBRN casualty estimation methodology because they are regarded as operationally insignificant, with little impact on a servicemember's performance.[7] 3rd degree burns are not explicitly considered in the NATO CBRN casualty estimation methodology because they are already considered as occurring within the with 2nd degree burn surface area.[8] This analysis will not address burns from fires secondary to the thermal pulse, and will not address optical burns (flash blindness or retinal burns). These are also not addressed as casualty mechanisms in the NATO CBRN casualty estimation methodology.

1st degree burns are painful and noticeable, making them a potential concern as a casualty criterion. 3rd degree burns pose a significant health risk, and a different medical challenge than 1st or 2nd degree burns. Further, burns are potentially prominent contributing factors to casualty estimates for nuclear weapons with yields above about 3 KT (at least until blast injury begins to dominate at megaton (MT) yields).

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[5] Institute for Defense Analyses, "CBRN Casualty Estimation and Support to the Medical CBRN Defense Planning & Response Project," Project Order CA-6-3079 Amendment No. 5 (Alexandria, VA: Institute for Defense Analyses 14 November 2013), 4.

[6] North Atlantic Treaty Organization (NATO), *AMedP-7.5: NATO Planning Guide for the Estimation of CBRN Casualties* FINAL DRAFT, STANAG 2553 (Brussels: NATO, study).

[7] L.A. LaViolet, et al., *Technical Reference Manual to Allied Medical Publication 7.5* (*AMedP-7.5*) *NATO Planning Guide for the Estimation of CBRN Casualties* (TRM), IDA Document D-5221 (Alexandria, VA: Institute for Defense Analyses, June 2016), 17.2

[8] LaViolet, et al.

This analysis builds on the prior work done to estimate casualties from 2nd degree flash burns from nuclear weapons.[9] It builds upon, and parallels, the methodology used to estimate the extent of the burn from exposure to thermal fluence from a nuclear weapon, the descriptions of symptoms and injury severity resulting from the burn, and the impact of medical treatment on the casualty estimate for burns. The final part of this analysis illustrates the significance (or lack thereof) of considering 1st and 3rd degree flash burns in the casualty estimate.

In addition to not considering 1st and 3rd degree flash burns, there is one prominent aspect of casualties from flash burns in conjunction with other injuries from nuclear weapons that is not considered in the NATO CBRN casualty estimation methodology: "Combined injuries." In this context, combined injuries are those that occur from multiple injury mechanisms at once: flash burns combined with radiation, radiation combined with blast injuries, blast injuries combined with flash burns, or all three mechanisms acting simultaneously. There is some research indicating that the combination of flash burns with radiation, or blast injuries with radiation, could result in casualties (including fatalities) at insult levels well below what might normally be regarded as significant.[10] In the NATO casualty estimation methodology, however, the decision was made not to consider this aspect of combined injuries. This was based on the judgment that "There are … very little data available on combined injuries. Thus, creating a model of such injuries is not feasible, and each injury is therefore treated separately, as if there is no synergy between the different types of injury."[11]

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[9] LaViolet, et al.

[10] Jessica L. Palmer, et al. "Development of a Combined Radiation and Burn Injury Model," *Journal of Burn Care and Research,* official publication of the American Burn Association, 32.2 (2011): 317–323. PMC. Web. 23 Feb. 2017, 4.

[11] *AMedP-7.5* TRM, 14-2.

2. Thermal Threshold, Q_t

The NATO CBRN casualty estimation methodology, as described in *AMedP-7.5*,[12] uses values for the thermal fluence threshold value (Q_t) for 2nd degree burns to bare skin from Sheldon Levin's report on models for estimation of nuclear casualties.[13] The reported value for Q_t of 2.60 Cal/cm^2 for 2nd degree burns is from an analysis of experimental data and modeling and simulation.[14]

The Defense Nuclear Agency (DNA) commissioned a study of how the thermal fluence from nuclear weapons would produce burns under various types of uniforms. This study, published in 1986, was conducted by Anthony Baba at Harry Diamond Laboratories of the U.S. Army Laboratory Command. The expressed purpose of this study was "…to provide the U.S. Army Nuclear and Chemical Agency (USANCA) with data on the incidence of skin burns under contemporary battlefield uniforms, caused by thermal radiation exposure on the tactical nuclear battlefield."[15] This study was later used in the development of nuclear weapon injury models,[16] including *AMedP-7.5*, for different clothing types.[17] These values are provided in Table 1, reproduced from Table 4-59 of *AMedP-7.5*.[18] Note that the values provided in the Levin and Baba reports are expressed in Cal/cm^2, while those in *AMedP-7.5* are expressed in kJ/m^2 to be consistent with internationally recognized metric units.

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12 North Atlantic Treaty Organization (NATO), *AMedP-7.5: NATO Planning Guide for the Estimation of CBRN Casualties* FINAL DRAFT, STANAG 2553 (Brussels: NATO, study).

13 Sheldon G. Levin, *The Effect of Combined Injuries from a Nuclear Detonation on Soldier Performance* (Espanola, NM: Technical Southwest, Inc., 1993), 24.

14 Ibid., 21.

15 Anthony J. Baba et al., *Incidence of Skin Burns under Contemporary Army Uniforms Exposed to Thermal Radiation from Simulated Nuclear Fireballs*, HDL-TR-2084 (Adelphi, MD: U.S. Army Laboratory Command, Harry Diamond Laboratories, December 1986), 7.

16 Levin, 24.

17 Baba et al., 24.

18 *AMedP-7.5* FD, 4-70.

Table 1. Thermal Fluence Threshold Values for Second Degree Burns for Various Uniform Types

Uniform/Clothing	Threshold Thermal Fluence (Q_t)	
	[Cal/cm2]	[kJ/m2]
Bare Skin	2.60	109
Battledress Uniform (BDU) + T-shirt	7.41	310
BDU + T-shirt + Airspace	15.1	630
Battledress Overgarment (BDO)	10.0	420
BDO + Airspace	16.0	670
BDO + BDU + T-shirt	31.1	1300
BDO + BDU + T-shirt + Airspace	48.0	2010

Source: *AMedP-7.5* FD, Table 4-59, 4-70.

For this study, it is necessary to estimate Q_t for 1st and 3rd degree burns. Baba's report, based on published 1st degree burn data, states "… the fluence required to produce a 50-percent incidence of first-degree burn (Q^1_{50}) is 0.8 of the fluence that is required to produce a 50-percent incidence of second-degree burns (Q^2_{50})."[19] Using a ratio of 0.8, and the Q_t of 2.60 Cal/cm^2 for 2nd degree burns, the calculated Q_t for 1st degree burns is 2.08 Cal/cm^2 (87.2 kJ/m^2). Baba also provides Q_t estimates for 1st degree burns under various uniform types.[20]

A similar factor for 3rd degree burns is not identified in Baba or Levin, so further analysis was required to estimate that value. An earlier analysis by M. K. Drake, et al., for the Defense Nuclear Agency[21] provides Q_{50} values for various degree burns at different yields, as shown in Table 2. (Q_{50} is the thermal fluence that results in a 50% probability of a particular burn under a determined set of circumstances. This is equivalent to the Qt for each burn type, unless otherwise identified,)

Table 2. Q_{50} (Cal/cm^2) Values for Various Degree Burns

	Yield (KT)					
	0.01	0.1	1	10	100	1,000
$1^\circ = Q^1_{50}$	1.9	1.9	2	2.3	2.8	3.2
$2^\circ = Q^2_{50}$	3.8	3.8	4	4.6	5.2	6.1
$3^\circ = Q^3_{50}$	5.8	5.8	5.9	7	8.1	9.3

M.K. Drake, et al., *An Interim Report on Collateral Damage*, DNA 4734Z, (Science Applications, Inc., La Jolla, CA, 1978), 5-39.

[19] Baba, 15.

[20] Baba, 24.

[21] M.K. Drake, et al., *An Interim Report on Collateral Damage*, DNA 4734Z, (Science Applications, Inc., La Jolla, CA, 1978), 5-39.

Although the magnitude of Q_{50} values reported by Drake, in the range of yields of interest (1-100 KT), range slightly higher than those in the reports by Baba or Levin, the ratios of these values are instructive and useful for estimating the Q_t for 3rd degree burns. Further, there is little other research available to estimate the incidence of 3rd degree flash burns on human skin. The average ratio of Q^3_{50} to Q^2_{50} in Table 2 is 1.53, and will be used to convert Baba's values for 2nd degree Q_t to values for 3rd degree Q_t. Using the ratios of 0.8 (1st:2nd) and 1.53 (3rd:2nd), a more complete table of Q_t for various burn levels is presented in Table 3.

Table 3. Thermal Fluence Threshold (Q_t) Values for Various Burns and Uniform Types

	1st Degree Burns		2nd Degree Burns		3rd Degree Burns	
Uniform/Clothing	**[Cal/cm²]**	**[kJ/m²]**	**[Cal/cm²]**	**[kJ/m²]**	**[Cal/cm²]**	**[kJ/m²]**
Bare Skin	2.08	87.2	2.61	109	3.98	167
Battledress Uniform (BDU) + T-shirt	5.93	248	7.41	310	11.3	474
BDU + T-shirt + Airspace†	12.0	504	15.1	630	23.0	963
Battledress Overgarment (BDO)	8.03	336	10.0	420	15.3	642
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BDO + BDU + T-shirt + Airspace†	38.4	1,610	48.0	2,010	73.5	3,070

† Airspace indicates looser clothing (i.e., clothing with airspace between the body and the garment), as opposed to fitted clothing.[22]

22 *AMedP-7.5* FD, Note to Table 4-59, 4-70.

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3. Simultaneous Incidence of Burns on a Nuclear Battlefield

A. Estimation of Total Body Surface Area (BSA)

In cases where the uniform type does not completely cover the body, the equations in the NATO CBRN casualty estimation methodology must account for both the injury to bare skin and the injury to clothed skin. This is done by estimating the fraction of total body surface area (% TBSA) that is burned bare skin, and the % TBSA burned under the uniform.[23]

The recommended values for the percentage of the body covered and not covered by uniform (12% not covered (bare skin) and 88% covered for unwarned cases, and 100% covered for warned cases)[24] are taken from page 24 of Levin's report.[25]

B. Calculation of Effective Insult

AMedP-7.5 Equation 4-38 is used to calculate the Effective CBRN Challenge for thermal fluence injuries (% TBSA) for personnel.[26] Using this equation, it is possible to calculate the fraction of the total body surface area burned with 1st, 2nd, or 3rd degree burns for any thermal fluence. An example of this is shown in Table 4. "BDU + T-shirt" is the uniform type selected. The "BDU + T-shirt" is assumed to cover 88% of the total body surface area, with 12% of the total body surface area uncovered (bare skin). Note that, in this table, the "Total Body Surface Area" is the sum of the fraction of total body surface area burned for the bare skin (uncovered) and under the uniform (covered). It should also be noted that, in a flash burn resulting from a nuclear detonation, the maximum body surface area burned cannot exceed 50% because it is assumed that the burn is from a point source and for a time period too short to allow the exposed individual to turn their body. These are injuries resulting from the exposure to the skin, with or without a uniform covering the skin. This does not account for any injuries resulting from the ignition of the uniform itself, or other fires secondary to the initial thermal pulse.

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[23] *AMedP-7.5* FD, 4-69.

[24] Ibid., 4-70.

[25] Levin, 24.

[26] *AMedP-7.5* FD, 4-69.

Table 4. Burns and Uniform Types

Thermal Fluence		Battledress Uniform (BDU) + T-shirt						
			Uncovered (Bare Skin)			Covered (Under Uniform)		
(Cal/cm^2)	(kJ/m^2)	Total Body Surface Area	1st Degree Burns	2nd Degree Burns	3rd Degree Burns	1st Degree Burns	2nd Degree Burns	3rd Degree Burns
2	84	-	-	-	-	-	-	-
2.5	105	2.2%	2.2%	-	-	-	-	-
3	126	3%	1.1%	2.0%	-	-	-	-
4	167	4%	0.6%	2.9%	0.3%	-	-	-
5	209	4%	0.5%	1.4%	2.5%	-	-	-
6	251	9%	0.4%	1.1%	3.2%	4.4%	-	-
7	293	21%	0.3%	0.9%	3.7%	15.7%	-	-
8	335	26%	0.3%	0.7%	4.0%	9.8%	10.8%	-
9	377	29%	0.2%	0.6%	4.2%	7.0%	16.9%	-
10	418	31%	0.2%	0.6%	4.4%	5.6%	20.6%	-
11	460	33%	0.2%	0.5%	4.6%	4.8%	23.3%	-
12	502	35%	0.2%	0.5%	4.7%	4.2%	15.9%	9.4%
13	544	36%	0.2%	0.4%	4.8%	3.7%	12.7%	14.4%
14	586	37%	0.1%	0.4%	4.9%	3.4%	10.8%	17.6%
15	628	38%	0.1%	0.4%	5.0%	3.1%	9.5%	20.0%
20	837	41%	0.1%	0.3%	5.2%	2.2%	6.2%	27.1%
25	1,046	43%	0.1%	0.2%	5.4%	1.7%	4.7%	30.8%
30	1,255	44%	0.1%	0.2%	5.5%	1.4%	3.9%	33.2%
35	1,464	45%	0.1%	0.2%	5.6%	1.2%	3.3%	34.8%
40	1,674	46%	0.0%	0.1%	5.6%	1.1%	2.8%	36.0%
45	1,883	46%	0.0%	0.1%	5.7%	0.9%	2.5%	36.9%
50	2,092	47%	0.0%	0.1%	5.7%	0.8%	2.2%	37.6%

From the Q_t values in Table 3, and illustrated by the example in Table 4, it can be seen that it is possible to get a 1% TBSA 1st degree burn (at 2.20 Cal/cm^2 (92 kJ/m^2) for bare skin) without suffering any 2nd or 3rd degree burns. It is not possible, however, to get a 2nd or 3rd degree burn without suffering any 1st or 2nd degree burns.

4. The Burn Injury Severity Profile

A 1st degree burn is characterized by damage to the epidermal layer of the skin, a skin depth of 100 nanometers. There is immediate pain and redness of skin similar to what occurs from sunburn, and the damage is reversible. There is no loss of fluid.[27] Healing occurs within 2–3 days.[28]

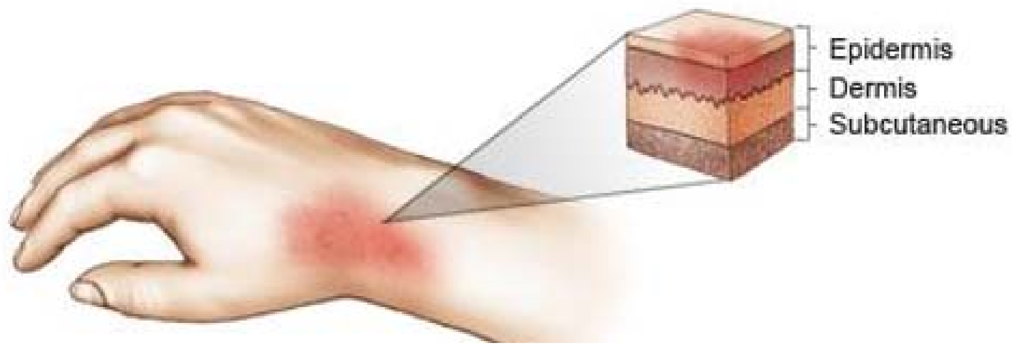

Figure 1. First Degree Burn[29]

2nd degree burns, or partial thickness burns, can damage the skin down to the dermal layer. 2nd degree burns result in prolonged pain, skin redness, swelling, and blisters. An eschar (scab) will form 6 to 24 hours postexposure, and eventually full skin regeneration will occur. 2nd degree burns will generally heal in 1–3 weeks; as the % TBSA burned increases, the healing time will increase as well.[30]

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27 Levin, *Effect of Combined Injuries*, 22.

28 LaViolet, et al., 17-2.

29 http://burnsurvivor.com/burn_types_first/.

30 LaViolet, et al., 17-2 – 17-3.

Figure 2. Second Degree Burn[31]

3rd degree burns, or full thickness burns, are characterized by irreversible full thickness skin damage to skin depths of more than 2,000 nanometers. Skin will appear charred and may lose elasticity. Skin will not regenerate normally, therefore grafting is necessary. There is no pain at the site of the 3rd degree burn because the nerve endings have been destroyed; however, there may be some pain in adjacent 2nd degree burn areas. The incidence of infection is common. Healing of full thickness burns is extremely slow and always results in a scar unless new skin is grafted.[32]

Figure 3. Third Degree Burn[33]

In the post-burn period for 2nd and 3rd degree burns, there is fluid loss (hypovolemia) and electrolyte imbalance, which may lead to a decrease in renal blood flow, followed by decreased cardiac output. As the blood pressure decreases, hemodynamic instability (shock) will occur. There is cell destruction in the burn area and a 5 to 40 percent loss of the total red blood cell mass, depending on the area and depth of the burn. Lymphocytes are reduced and the immune system is compromised, resulting in an increased probability

[31] http://burnsurvivor.com/burn_types_second/.

[32] LaViolet, et al., 17-3.

[33] http://burnsurvivor.com/burn_types_third/.

of infection.[34] The severity of these symptoms varies depending on the type of burn, the burn location, and the % TBSA.[35] These "systemic" effects are considered in the NATO CBRN casualty estimation methodology within the "Cardiovascular" and "Immune" systems. Cadiovascular symptoms range from dizziness or a slight feeling of light headedness, to shock and uncontrollable bleeding. Immune symptoms range from a slight fever, sometimes with a headache, to overwhelming infections.

A. Burn Symptom Severity Levels

The description of injury severity for a specific exposure in the NATO CBRN casualty estimation methodology is derived from the severity of symptoms resulting from that injury. Burn symptoms are associated with three different physiological systems: cardiovascular system (hypotension and bleeding), immune system (infection), and skin. The symptoms and associated severity levels for these three systems are tabulated in the TRM,[36] and reproduced in Table 5.

Table 5. Burn Symptoms and Severity Levels

Severity	Cardiovascular	Immune	Skin
0	No observable injury	No observable injury	No observable injury
1	Slightly feeling of light headedness	Slight fever and headache	Epidermal (1st degree) burns over small body surface area characterized by skin redness, swelling, and blistering; persistent pain at burn site
2	Unsteadiness upon standing quickly; possible micro-hemorrhaging	Aching joints; fever; lack of appetite; sores in mouth/throat	Partial thickness (2nd degree) burns over large body surface area combined with some full thickness (3rd degree) burns; pain at sites of partial thickness burns; potential for fluid loss through burn sites
3	Severe dizziness; faints upon standing quickly; may have difficulty stopping any bleeding	High fever results in shakes, chills and aches all over	Partial (2nd degree) and full thickness (3rd degree) burns over up to 30% of the body surface area; limited pain due to nerve damage from 3rd degree burns; significant fluid loss through burn sites
4	Shock; rapid and shallow breathing; skin cold, clammy and very pale; difficulty or inability to stop any bleeding; crushing chest pain	Delirium from fever; overwhelming infections	≥ 30% TBSA with partial (2nd degree) and full thickness (3rd degree) burns

Source: LaViolet, et al., Table 139, 17-6.

[34] Marvin K. Drake and William A. Woolson, *EM-1—Capabilities of Nuclear Weapons, Chapter 14—Effects on Personnel*, DNA-EM-1-CH-14 (San Diego, CA: Defense Nuclear Agency, March 1993), 14-5b.

[35] LaViolet, et al., 17-2 – 17-3.

[36] Ibid., Table 139. 17-6.

Note that each of the severity levels address 1st, 2nd, and 3rd degree burns. From the flash of a nuclear weapon, the burns associated with a specific level of thermal fluence are likely to include any of the three degrees of burns, as the thermal fluence exceeds the Q_t for each degree of burn. Thus, a thermal fluence sufficient to cause blistering at the burn site (a severity level 1 skin symptom of 2nd degree burns) is also sufficient to cause an area of 1st degree burns surrounding the 2nd degree burn site. Similarly, a thermal fluence sufficient to cause a severe 2nd degree burn will potentially result in an area of 3rd degree burns within the burn site.

A 1st degree burn only involves the surface of the skin – no other physiological system – and will not exceed Severity Level 1. For a thermal fluence that results in 1st degree burns ONLY (less than Q_t for 2nd degree burns), even as the %BSA increases, the symptom severity levels will be no worse than Severity Level 1. The system symptom severity levels do not progress to higher levels without the consideration of at least 2nd degree burns.

3rd degree burns involve the full thickness of the skin, and result in cardiovascular system and immune system symptoms. For 3rd degree burns to be present, the thermal fluence is already sufficient to have produced 1st and 2nd degree burns. Thus, the lowest severity level exhibited by a 3rd degree burn is Severity Level 2.

B. Burn Injury Severity Levels and Progressions

The second aspect of CBRN casualty estimation is the time progression of the symptom severity at a given range of injury or insult. This defines the times at which a specific symptom severity will exist and allows an estimate of when, and how long, an individual will be a casualty at the specified severity level. For burns as a result of exposure to the thermal fluence from a nuclear detonation, the fraction of the total body surface area burned is what dictates the severity of injury. Changes in uniform type may be expected to alter the percentage of the total body surface area burned—for example, bare skin has a significantly lower threshold for 2nd degree (partial thickness) burns than skin encased in a standard BDU. Thus, physiological descriptions of anticipated injury progressions and symptoms associated with varying percentages of total body surface area burned were used to derive the thermal insult table.[37] The thermal insult ranges for *AMedP-7.5* are defined in terms of the fraction of the total body surface area burned with 2nd degree burns, including any 3rd degree burns encompassed in that area. There are five defined thermal insult ranges, shown in Table 4-60 of *AMedP-7.5*[38] and reproduced here as Table 6.

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[37] Levin. *Effect of Combined Injuries*; AFRRI, *Medical Management of Radiological Casualties*; and Baba et al., *Incidence of Skin Burns*.

[38] *AMedP-7.5* FD, Table 4-60, 4-72.

There is a progression of injury over time that is modeled for each of the dose ranges. For the NATO CBRN casualty estimation methodology, the casualty estimate is based upon "Injury Profiles," which were derived by overlaying the symptom progressions for a given insult range and mapping the highest severity from any physiological system into the Injury Profile.

Table 6. Thermal Insult Ranges

Thermal Insult Range (2° or higher % TBSA)	Set of Symptoms
< 1	No observable injury[a]
1 – < 10	1st, 2nd and possible 3rd degree burns; electrolyte imbalance; pain
10 – < 20	Upper GI discomfort; 1st, 2nd and possible 3rd degree burns; electrolyte imbalance; increased pain
20 – < 30	Upper GI discomfort; 1st, 2nd and possible 3rd degree burns; fluid loss; decreased renal blood flow; compromise of the immune system; pain; lethality in 10%[b]
≥ 30	Upper GI discomfort; 2nd and 3rd degree burns; hypovolemia; decreased renal blood flow; shock resulting from blood pressure decrease; cardiac distress; toxemia; multiple organ failure; lethality in ≥ 50%[b]

[a] < 1% TBSA may include a larger area of 1st degree burns.

[b] Estimation of burn lethality is approximate.

Source: *AMedP-7.5* FD, Table 4-60, 4-72.

Table 4-61 of *AMedP-7.5*,[39] reproduced here in Table 7, describes the time progression of a 2nd degree burn injury severity at various levels of fraction of the total body surface area burn (the "No observable injury" level is not included). The consideration of 1st and 3rd degree burns as part of the spectrum of thermal injury may result in some revisions to this table, particularly for 1st degree burns in the absence of any other thermal injury, and for significant areas of 3rd degree burns. Note that some symptoms may persist for more than the 336-hour (2-week) time frame included in this table, primarily for 2nd degree burns (with 3rd degree included) greater than 20% TBSA, which will be symptomatic for very long periods of time, in some cases months, well beyond the 1,000-hour (6-week) planning period considered in the NATO CBRN casualty estimation methodology.

[39] *AMedP-7.5* FD, Table 4-61, 4-72.

Table 7. 2nd Degree (with 3rd Degree Included) Burn Injury Profiles

Time Point (hr)	Insult Range: 1 – < 10% TBSA	10 – < 20% TBSA	20 – < 30% TBSA	≥ 30% TBSA
0.1	1	2	3	3
24	1	2	3	4[a]
48	2	2	3	
336	0	1	3	

[a] Death is modeled to occur at this point, based on the default value of the parameter $T_{death\text{-}CN\text{-}SL4}$ in *AMedP-7.5*.

Source*: AMedP-7.5* FD, Table 4-61, 4-72.

1. The 1st Degree Burn Injury Severity Profile

Since the more serious injury dominates in the NATO CBRN casualty estimation methodology, the only 1st degree burn injury progression of concern is that which does not involve a 2nd or 3rd degree burn. As illustrated in Table 4, it is possible to get greater than 1% TBSA 1st degree burns without 2nd degree burns. However, given the Q_t for bare skin and the various uniform types in Table 3, a 1% TBSA 2nd degree burn will occur prior to exceeding a 10% TBSA 1st degree burn. Therefore, the 1st degree burn insult range is 1–<10% TBSA. (Note that less than 1% TBSA is regarded as “No observable injury.”)

Further, a 1st degree burn involves only the surface of the skin – no other physiological system – and will not exceed Severity Level 1. Healing is reported to occur within 2–3 days[40] or up to a week.[41] For a thermal fluence that results in 1st degree burns ONLY (less than Q_t for 2nd degree burns), the injury severity profile would be as presented in Table 8.

[40] LaViolet, et al., 17-2.

[41] http://www.mayoclinic.org/diseases-conditions/burns/basics/symptoms/con-20035028, downloaded 2 February 2017.

Table 8. 1st Degree Burn Injury Profiles

Time Point (hr)	Insult Range 1 – < 10% TBSA
0.1	1
24	1
48	1
336	0

2. The 3rd Degree Burn Injury Severity Profile

3rd degree burns involve the full thickness of the skin and include cardiovascular system and immune system symptoms. For 3rd degree burns to be present, the thermal fluence is already sufficient to have produced 1st and 2nd degree burns. Thus, the lowest severity level exhibited by a 3rd degree burn is Severity Level 2, at least until a significant time has passed, and then only for the lowest insult range. Criteria for medical management of burns (which will be addressed later in this analysis) also change based on the fraction of the total body surface area with 2nd or 3rd degree burns; the criteria for transferring patients to a burn center include the presence of 20% TBSA or greater 2nd degree burns, or 3rd degree burns exceeding 5% TBSA.[42] Further, the likelihood of survival is reduced as the fraction of the total body surface area of 3rd degree burn increases, until death is more likely than not at 20% TBSA for 3rd degree burns.[43]

From the Q_t defined in Table 3 and the example uniform with 12% bare skin used in Table 4, it is possible to illustrate the fraction of the total body surface area of 1st, 2nd, and 3rd degree burns, as well as that for the combined 2nd and 3rd degree burns and the total of all burns, as shown in Figure 4. (Note the bold horizontal lines that illustrate the insult bands of 1, 10, 20, and 30% TBSA expressed in Table 7.)

Of particular interest is the fraction of the total body surface area burned for each type of burn (2nd and 3rd degree) within the insult bands identified in Table 7. For the example uniform combination used in Table 4 (with 12% of the total body surface area as bare skin and 88% of the total body surface area under a BDU plus t-shirt), the thermal fluence sufficient to cause a 1% TBSA burn is 2.69 Cal/cm^2 (113 kJ/m^2), and the burn resulting from this fluence is a 1% TBSA 2nd degree burn, and no 3rd degree burn (although there is a 1.65% TBSA 1st degree burn that is not considered). At a fluence of 3.98 Cal/cm^2

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[42] *Textbook on Military Medicine for Conventional Warfare: Ballistic, Blast, and Burn Injuries (TMM)* Ch 11, p 367

[43] "In general, the cut-off point 20% TBSA score seems to provide maximum separation between survivors and fatalities" B.S. Atiyeh, et al., "State of the Art in Burn Treatment," *World Journal of Surgery*, 29, 2005, 137.

(167 kJ/m^2) there is a 3.3% TBSA 2nd degree burns, and 3rd degree burns begin to occur. The 3rd degree burns occur on the bare skin, which has a lower Q_t than the uniform, and this results in an estimate of 3rd degree (and lesser) burns to the bare skin, and only 2nd degree (and lesser) burns under the uniform. A 1% TBSA of 3rd degree burns occurs at 4.12 Cal/cm^2 (172 kJ/m^2), which is coincident with a 2.4% TBSA 2nd degree burn. Note that in Table 5 the description of Severity Level 2 ("Moderate") Skin Symptoms includes "Partial thickness (2nd degree) burns over large body surface area combined with some full thickness (3rd degree) burns …." The first insult band in Table 6 extends up to 10% TBSA for combined 2nd and 3rd degree burns, and for this uniform combination 10% TBSA occurs at 7.54 Cal/cm^2 (316 kJ/m^2). The 10% TBSA includes 6.20% TBSA 2nd degree burns and 3.80% TBSA 3rd degree burns. The thermal fluence sufficient to cause a 20% TBSA burn is 8.64 Cal/cm^2 (361 kJ/m^2), and this includes 15.85% TBSA 2nd degree burns and 4.15% TBSA 3rd degree burns.

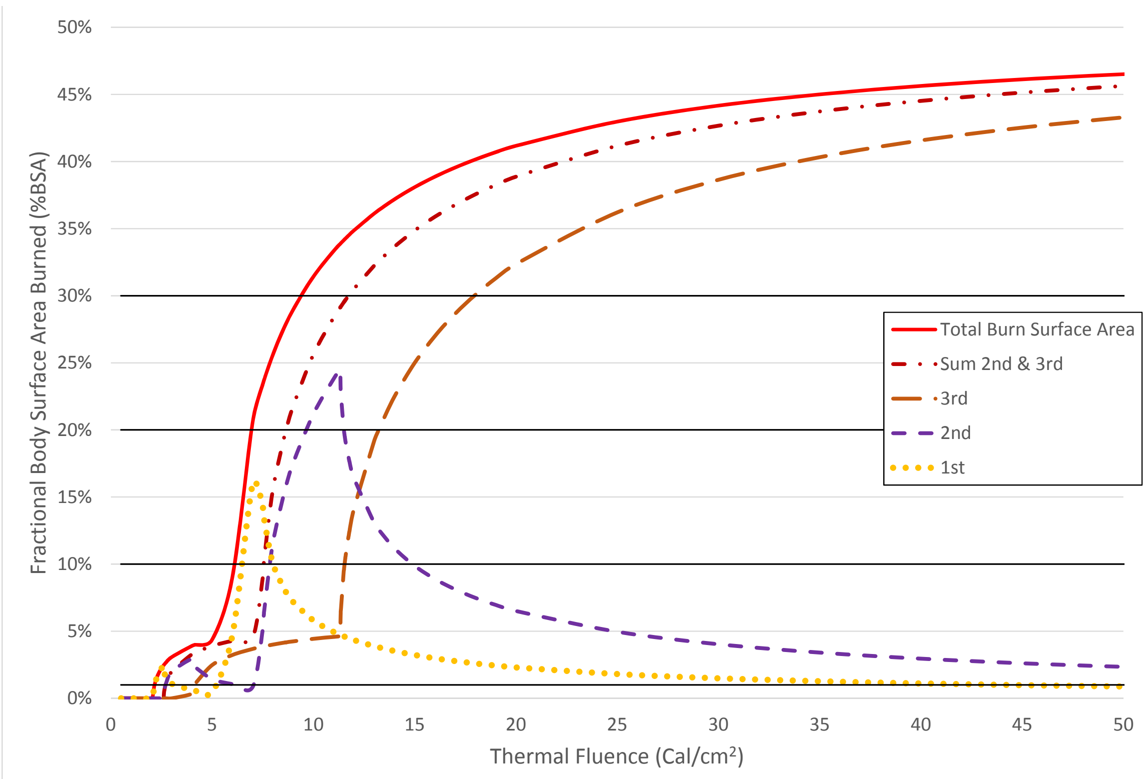

Figure 4. Flash burns from nuclear thermal fluence to an individual with 12% bare skin and 88% BDU + T-shirt.

When regarding a uniform combination that does not include bare skin, the incidence of 3rd degree burns is negligible until there is more than a 25% TBSA 2nd degree burn. This is illustrated in Figure 5, for the uniform type "BDO + BDU + T-shirt + Airspace." The horizontal axis provides a quantitative illustration of the added protection provided by this uniform: In Figure 4 the axis extends to 50 cal/cm^2, while in Figure 5 it extends out to 500 cal/cm^2. This correlates to the two different values of Q_t for the different uniform types (from Table 2): 7.41 cal/cm^2 (310 kJ/m^2) for BDU + T-shirt and 31.1 cal/cm^2 (1,300 kJ/m^2) for BDO + BDU + T-shirt + Airspace for 2nd degree burns under the uniform.

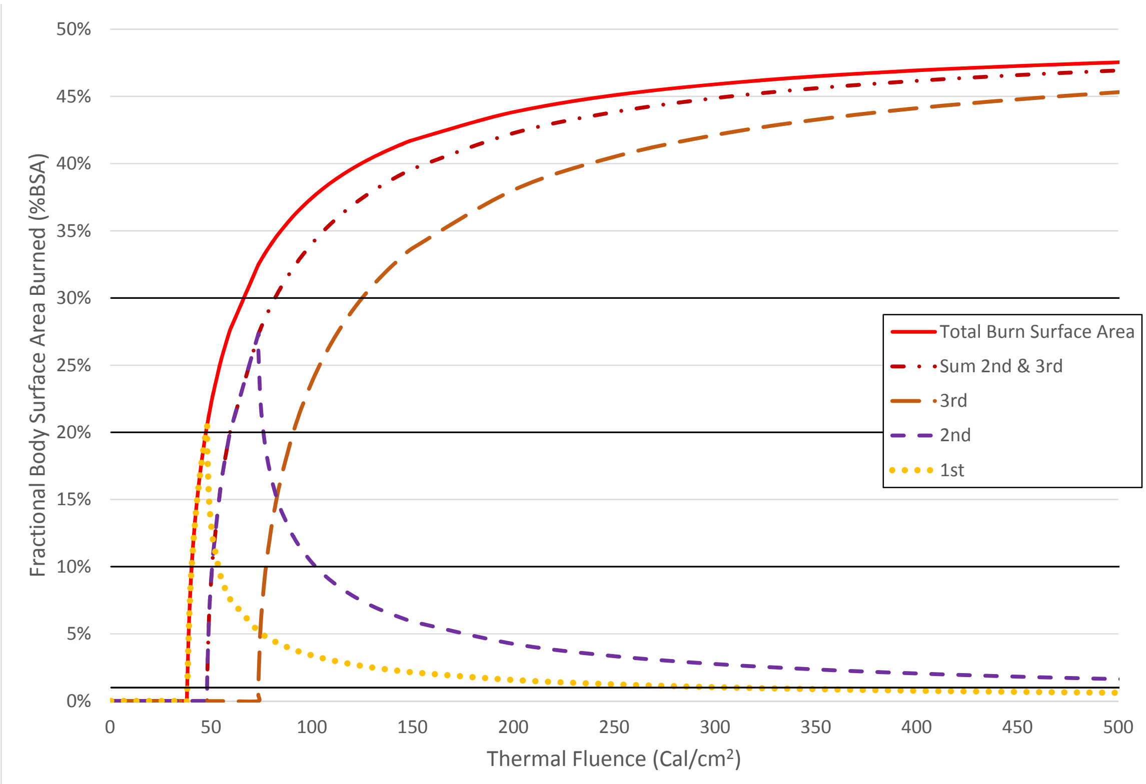

Figure 5. Flash burns from nuclear thermal fluence to an individual with no bare skin and 100% BDO + BDU + T-shirt + Airspace.

Although a 4% TBSA 3rd degree burn is not negligible, it can be interpreted as a Severity Level 2 (Moderate) injury. When this level of injury occurs because of the presence of bare skin, this becomes a particular concern for unwarned troops, who have not covered exposed skin to protect themselves from the thermal effects of a nuclear weapon; a "warned" nuclear posture would normally include covering any exposed bare skin. Considering this, and the increased lethality of larger area (20% TBSA) 3rd degree burns, leads to the injury profiles presented in Table 9 for consideration of 3rd degree burns without consideration of the other burns (or other injuries of any type) that also may be present.

Table 9. 3rd Degree Burn Injury Profiles, Without Consideration of 1st or 2nd Degree Burns

Time Point (hr)	Insult Range		
	1 – < 5% TBSA	5 – < 20% TBSA	≥ 20% TBSA
0.1	2	3	3
24	2	3	4[a]
48	2	3	
336	2	3	

[a] Death is modeled to occur at this point, based on the default value of the parameter $T_{death\text{-}CN\text{-}SL4}$ in *AMedP-7.5*.

Source: *AMedP-7.5* FD, 1-14.

Given the incidence of 2nd and 3rd degree burns illustrated in Figure 5 (which includes some bare skin) and Figure 6 (which does not include bare skin), it can be seen that a 5% TBSA 3rd degree burn does not occur until the total area with 2nd and 3rd degree burns exceeds 20% TBSA. Thus, when 2nd and 3rd degree burns are considered explicitly, similar to the manner of the the current NATO CBRN casualty methodology, there appears to be no reason to change the burn injury profiles used. No revision of the "2nd Degree (with 3rd Degree Included) Burn Injury Profiles" (Table 7) is recommended.

5. The Impact of Medical Treatment on the Burn Casualty Estimate

One of the unique aspects of the NATO CBRN casualty estimation methodology, as updated in *AMedP-7.5*, is the consideration of medical treatment in the casualty estimate.[44] For a casualty estimate that considers medical treatment, the injury profile (such as Table 7, Table 8, or Table 9) is followed until the point at which medical treatment begins, and then the medical treatment outcome reporting table (MTOR) is used to determine the outcome.

A. The Impact of Medical Treatment on the 2nd Degree Burn Casualty Estimate

The MTOR presented in *AMedP-7.5*[45] is included here as Table 10.

Table 10. Thermal Fluence Medical Treatment Outcome Reporting

Insult Range [% TBSA]	DOW	CONV	RTD
1 – < 10	0%	0%	Day 15: 100%
10 – < 20	0%	0%	Day 23: 100%
20 – < 30	0%	Day 33: 50%	Day 33: 50%
30 – < 45	Day 9: 30%	Day 44: 70%	0%
≥ 45	Day 9: 50%	Day 51: 50%	0%

Soure*: AMedP-7.5* FD, Table 4-62, 4-72.

B. The Impact of Medical Treatment on the 1st Degree Burn Casualty Estimate

Since the more serious injury dominates in the NATO CBRN casualty estimation methodology, the only 1st degree burn injury of concern is that which does not involve a 2nd or 3rd degree burn. Therefore, the 1st degree burn insult range of concern for casualty estimation is 1–<10% TBSA of 1st degree burn only. (Note that less than 1% TBSA is regarded as "No observable injury.")

[44] TRM, 1-1.

[45] *AMedP-7.5* FD, Table 4-62, 4-72.

A 1st degree burn requires only topical treatments, and typically is treated on an outpatient basis.[46] This can be accomplished in relatively little time – perhaps within the first hour, certainly within the first day of being seen at a medical treatment facility. For a flash burn of 1-10% TBSA 1st degree burns ONLY, the MTOR table would be as presented in Table 11.

Table 11. 1st Degree Burn Medical Treatment Outcome Reporting

Insult Range [% TBSA]	DOW	CONV	RTD
1 – < 10	0%	0%	Day 2: 100%

C. The Impact of Medical Treatment on the 3rd Degree Burn Casualty Estimate

3rd degree burns involve the full thickness of the skin, and include cardiovascular system and immune system symptoms. From Table 9, the lowest severity level exhibited by a 3rd degree burn is Severity Level 2, and then only for the lowest insult range of 1-4% TBSA and with concomitant 1st and 2nd degree burns. Although a 1-5% TBSA 3rd degree burn is not negligible, it can be treated at a Role III hospital, without evacuation to a higher level hospital or burn center. Criteria for medical management of burns also change based on the fraction of the total body surface area with 2nd or 3rd degree burns; the criteria for transferring patients to a burn center include the presence of 20% TBSA or greater 2nd degree burns, or 3rd degree burns exceeding 5% TBSA.[47] Further, the likelihood of survival is reduced as the fraction of the total body surface area of the burn increases, until death is more likely than not at 20% TBSA for 3rd degree burns.[48]

AMedP-7.5 defines CONV as "a 'patient who is "mostly ambulatory" [and] requires limited therapeutic intervention and administration of oral medications performed by the patient.'[49] Alternatively, patients who are evacuated out of theatre for long-term recovery. Thus, a CONV was previously wounded in action (WIA), but currently requires either no or minimal in-theatre medical resources. Casualties whose recovery time can be estimated will RTD; those with an unknown period of recovery or long-term/permanent disability will remain CONV."[50] The current NATO CBRN casualty estimation methodology uses

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[46] http://www.aafp.org/afp/2012/0101/p25.html downloaded 13 February 2017.

[47] *TMM*, Ch 11, 367.

[48] "In general, the cut-off point 20% TBSA score seems to provide maximum separation between survivors and fatalities." B.S. Atiyeh, et al., "State of the Art in Burn Treatment," *World Journal of Surgery*, 29, 2005, 137.

[49] NATO, *AMedP-13(A)*, 2-15.

[50] NATO, *AMedP-7.5 FD*, 1-12.

an equation that predicts hospitalization time generated by experts who reviewed the cases of 352 patients.[51]

Hospitalization time could correlate to time until CONV or time until RTD, and was used for both CONV and RTD because there were insufficient data to try to distinguish. Specifically, the equation used in the development of *AMedP-7.5* for length of hospital stay is given by Wong and Ngim:[52]

$$Length\ of\ hospital\ stay\ (days) = 1.93 + 0.93 \times \%BSA + 3.20\ \times full\ thickness\ \%BSA + 0.14 \times age + 6.97 \times status\ of\ respiratory\ injury,$$

where "*status of respiratory injury*" equals 0 if there is no respiratory injury and 1 if there is respiratory injury. *Full thickness %BSA* was set equal to the *%BSA* for the consideration of the impact of medical treatment for 3rd degree burns only. Table 12 contains results from this equation that are relevant for the insult ranged presented in the MTOR table, Table 13. Given the large amount of uncertainty in planning for medical care on the nuclear battlefield, the final column in Table 12 provides recommended values for the length of hospital stay when considering 3rd degree burns only.

Table 12. Length of Hospital Stay from 3rd Degree Burn Injury

% TBSA[a]	Age[b]	Respiratory Injury	Length of Hospital Stay (days)	Average	Planning Value
1	25	No	9.56	13.05	14
1	25	Yes	16.53		
2.5	25	No	15.755	19.24	21
2.5	25	Yes	22.725		
5	25	No	26.08	29.57	30
5	25	Yes	33.05		
10	25	No	46.73	50.22	50
10	25	Yes	53.7		
15	25	No	67.38	70.87	70
15	25	Yes	74.35		
20	25	No	88.03	91.52	90
20	25	Yes	95.00		
25	25	No	108.7	112.2	120
25	25	Yes	115.7		

[51] M. K. Wong and R. C. K. Ngim, "Burns Mortality and Hospitalization Time–a Prospective Statistical Study of 352 Patients in an Asian National Burn Centre," *Burns* 21, no. 1 (1995): 39–46.

[52] Ibid., 42.

Note: Full thickness %BSA was set to 0 because the *AMedP-7.5* %BSA already includes full thickness burns. Although this may result in an underestimate of recovery time, we made this choice in part to offset the likely overestimate in recovery time resulting from using an equation derived from the general population instead of the military population.

[a] The %BSA values were chosen be representative across several insult ranges.

[b] The age of 25 was chosen to represent the military population.

The *Textbook on Military Medicine for Conventional Warfare: Ballistic, Blast, and Burn Injuries* devotes an entire section of the chapter on "The Management of Burn Injury" to evacuation of casualties with thermal injuries. For those patients meeting the criteria for evacuation, the recommendation is that "Thermally injured patients are best moved during the first 48 hours after being injured …"[53] This would result in patients with greater than a 5% TBSA 3rd degree burn becoming CONV (by evacuation to a burn center) at 48 hours. However, the medical and logistical difficulties of evacuating burn casualties warrant extending that time when necessary.

To estimate the fraction that becomes DOW instead of CONV, the NATO CBRN casualty estimation methodology used an equation provided by Wong and Ngim.[54] In their analysis, these authors found that only the fraction of the total body surface area for the total burn area (*% TBSA*) and the *status of respiratory injury* (not the *Full thickness % TBSA*) had a significant impact. From these considerations, it is clear that the DOW values will remain the same in the MTOR from 2nd degree to 3rd degree.

A MTOR table developed for when 3rd degree flash burns are the sole consideration, therefore, would be as presented in Table 13.

Table 13. Medical Treatment Outcome Reporting For 3rd Degree Burn Only

Insult Range [% TBSA]	DOW	CONV	RTD
1 – < 2.5	0%	0%	Day 14: 100%
2.5 – < 5	0%	0%	Day 21: 100%
5 – < 10	0%	Day 2: 50%	Day 30: 50%
10 – < 30	0%	Day 2: 100%	0%
30 – < 45	Day 9: 30%	Day 2: 70%	0%
≥ 45	Day 9: 50%	Day 2: 50%	0%

It should be recognized, however, that 3rd degree flash burns on the nuclear battlefield do not occur in the absence of any other burns. In the discussion above of the simultaneous incidence of burns on the nuclear battlefield (Table 4), an individual in the example uniform (12% bare skin and 88% BDU + T-shirt) is unlikely to get a 5% TBSA 3rd degree burn until

[53] *TMM*, 11, 368.

[54] Wong and Ngim, "Burns Mortality and Hospitalization Time," 42.

the combined 2nd and 3rd degree burn exceeds 33% TBSA. From Figure 5, for an individual in a more protective uniform (BDO + BDU + T-shirt + Airspace), the fractions of 3rd and 2nd degree burns are similar. The fact that the presence of 3rd degree burns is associated with 2nd degree burns should not be ignored, or assumed away, when considering 3rd degree burns. The recommendation, therefore, is that an MTOR table for 3rd degree flash burns include a criterion for fraction of the total body surface area burned by both 2nd and 3rd degree burns, as presented in Table 14. Note that this is very similar to the table in *AMedP-7.5*, with the exception that CONV status is effective on Day 2, consistent with the recommendations for transferring patients with 20% TBSA or greater 2nd degree burns, or 3rd degree burns exceeding 5% TBSA, to a burn center, and this evacuation should occur during the first 48 hours after being injured. Note that this means that, unlike for other CBRN insults, burn casualties are evacuated as early as possible to transfer them to a burn center. DOW casualties are still specified for thermal injuries, but these casualties occur after evacuation to the burn center.

Table 14. Medical Treatment Outcome Reporting For 3rd Degree Burn in the Presence of 2nd Degree Burn

Insult Range [%BSA]				
2nd & 3rd Degree Burn	**3rd Degree Burn ONLY**	**DOW[a]**	**CONV[b]**	**RTD**
1 – < 10	1 – < 2.5	0%	0%	Day 15: 100%
10 – < 20	2.5 – < 5	0%	0%	Day 23: 100%
20 – < 30	5 – < 10	0%	Day 2: 50%	Day 33: 50%
30 – < 45	10 – < 20	Day 9: 30%	Day 2: 70%	0%
≥ 45	≥ 20	Day 9: 50%	Day 2: 50%	0%

[a] DOW casualties from burns occur after evacuation to the burn center.

[b] CONV occurs because of evacuation to a burn center.

Note: RED font highlights the changes from Table 16.

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6. An Illustrative Scenario

A final consideration in adding 1st and 3rd degree burns into the planning for CBRN casualties is "Does it make a significant difference in the casualty estimate?" An earlier analysis, *Casualty Estimation for Nuclear and Radiological Weapons*,[55] illustrated the applicability of using the NATO CBRN casualty estimation methodology for improvised nuclear devices (IND) and conventional nuclear weapons. The ten kiloton (10 KT) surface (ground) burst (height of burst (HoB) = 1m) generic fission weapon scenarios from that analysis will be used to compare the current NATO CBRN casualty estimation methodology with the proposed revisions made above. Figure 6 illustrates the magnitude of the radiation, blast, and thermal energies for a 10KT ground burst on the operational unit scenario, a light infantry battalion (LIBN) task force, with all personnel wearing the example uniform (12% bare skin and 88% BDU + T-shirt), and afforded protection from radiation and thermal exposures by vehicles, structures, or emplacements.

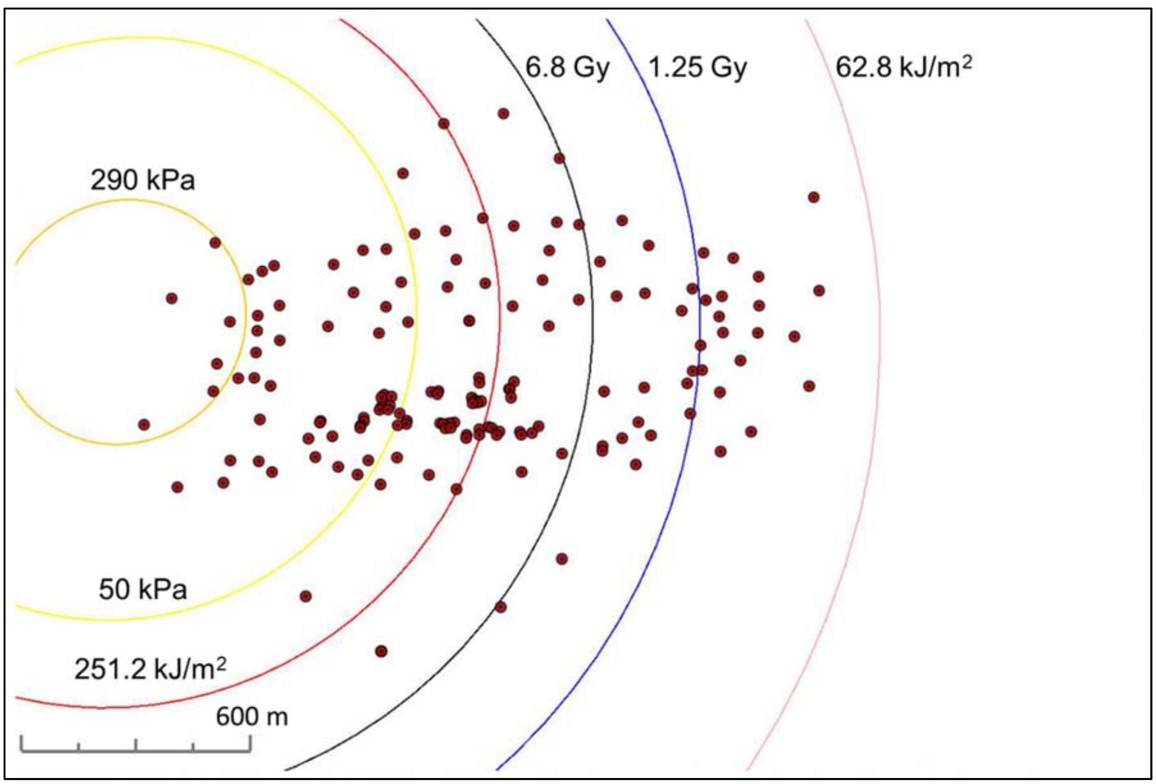

Figure 6. 10KT Ground Burst on Task Force[56]

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[55] Curling, C.A, *Casualty Estimation for Nuclear and Radiological Weapons*, IDA P-5220, June 2016, 1.

[56] Op. cit, 8.

Table 15 provides the effective nuclear weapon challenge estimated for the personnel in the LIBN in the 10KT surface burst scenario. The cells in this table are defined by the dose bands for radiation (R), blast static overpressure (B) and thermal exposures (T) as described in *AMedP-7.5*. The upper left cell (R:<125cGy, B:<50kPa, T: <1% TBSA) enumerates the personnel unaffected by the prompt effects – in this case, 71.

Table 15. Effective Nuclear Weapon Challenge, 10 KT, Ground Burst, LIBN, All Personnel Protected[57]

CHALLENGE:	T: <1% TBSA	T: 1%-10% TBSA	T: 10%-20% TBSA	T: 20%-30% TBSA	T: > 30% TBSA
R:<125cGy / B:<50kPa	71	94	0	0	0
R:125-300cGy / B:<50kPa	9	47	0	0	0
R:300-450cGy / B:<50kPa	7	7	0	0	0
R:450-830cGy / B:<50kPa	7	41	0	2	0
R:>830cGy / B:<50kPa	123	16	57	33	43
R:<125cGy / B:50-140kPa	0	0	0	0	0
R:125-300cGy / B:50-140kPa	0	0	0	0	0
R:300-450cGy / B:50-140kPa	0	0	0	0	0
R:450-830cGy / B:50-140kPa	0	0	0	0	0
R:>830cGy / B:50-140kPa	64	0	0	0	99
R:<125cGy / B:140-240kPa	0	0	0	0	0
R:125-300cGy / B:140-240kPa	0	0	0	0	0
R:300-450cGy / B:140-240kPa	0	0	0	0	0
R:450-830cGy / B:140-240kPa	0	0	0	0	0
R:>830cGy / B:140-240kPa	50	0	0	0	24
R:<125cGy / B:240-290kPa	0	0	0	0	0
R:125-300cGy / B:240-290kPa	0	0	0	0	0
R:300-450cGy / B:240-290kPa	0	0	0	0	0
R:450-830cGy / B:240-290kPa	0	0	0	0	0
R:>830cGy / B:240-290kPa	1	0	0	0	3
R:<125cGy / B:>290kPa	0	0	0	0	0
R:125-300cGy / B:>290kPa	0	0	0	0	0
R:300-450cGy / B:>290kPa	0	0	0	0	0
R:450-830cGy / B:>290kPa	0	0	0	0	0
R:>830cGy / B:>290kPa	0	0	0	0	21

[57] Op. cit., 10.

Table 16 provides an estimate of the new casualties occurring by day in this scenario, as calculated using the NATO CBRN casualty estimation methodology as described in *AMedP-7.5*.

Table 16. New Casualties Occurring (by Day) from Prompt Nuclear Effects, 10 KT Ground Burst, LIBN, Protection Considered and with Medical Treatment (including G-CSF)*[58]

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
KIA (Nuclear)	21	0	0	0	0	0	0	0	0	0
DOW (Nuclear)	0	266	47	27	17	12	2	67	75	0
Sum of New Fatalities	21	266	47	27	17	12	2	67	75	0
New WIA (Nuclear)	725	0	0	0	0	0	0	0	0	0
New CONV (Nuclear)	0	9	0	0	0	0	0	0	47	63
New RTD	0	0	0	0	0	0	0	0	94	0

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.

A. Casualties from an Illustrative Nuclear Weapon Example with Explicit Consideration of 2nd and 3rd Degree Flash Burn

To explicitly consider 3rd degree burns, along with 2nd degree burns, in the casualty estimate, use Table 14 instead of the MTOR in *AMedP-7.5* (Table 10, above). The thermal insult ranges in Table 14 are the same as in *AMedP-7.5*, so there would be no change in the effective nuclear weapon challenge show in Table 15. The only change would be in the time at which a WIA would be declared CONV:

- "20 – < 30% TBSA" from Day 33 to Day 2;
- "30 – < 45% TBSA" from Day 44 to Day 2; and
- "≥ 45% TBSA" from Day 51 to Day 2.

Because of consideration from radiation and blast injuries, this would apply for those individuals with thermal injuries of 20% TBSA or more, but not those who are DOW on Day 2 with blast insults greater than or equal to 290 kPa, or who are DOW on or before Day 2 from initial ionizing radiation exposure (less than about 50 Gy). Consistent with the annotations to Table 14, DOW occurring after Day 2 with these combinations of insults would occur after evacuation to the burn center. This changes the values in Table 16 for 28 individuals: the row labeled "New CONV (Nuclear)" by moving the 28 individuals in the

[58] Op. cit., 32.

column "DAYS 15-30" to add to 9 individuals in the column "DAY 2" column, for a total of 37 in that column, 19 in the column "DAYS 15-30," and 63 in the column "DAYS 30+" of that row. Note that the new MTOR shown in Table 14 does not change any DOW or RTD values. This results in a revised table of "New Casualties Occurring (by Day) from Prompt Nuclear Effects, 10 KT Ground Burst, LIBN, Protection Considered and with Medical Treatment (including G-CSF)," as illustrated in Table 17.

Table 17. New Casualties Occurring (by Day) from Prompt Nuclear Effects, 10 KT Ground Burst, LIBN, Protection Considered and with Medical Treatment (including G-CSF)*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
KIA (Nuclear)	21	0	0	0	0	0	0	0	0	0
DOW (Nuclear)	0	266	47	27	17	12	2	67	75	0
Sum of New Fatalities	21	266	47	27	17	12	2	67	75	0
New WIA	725	0	0	0	0	0	0	0	0	0
New CONV (Nuclear)	0	37	0	0	0	0	0	0	19	63
New RTD	0	0	0	0	0	0	0	0	94	0

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.

RED font highlights the changes from Table 16.

B. Casualties from an Illustrative Nuclear Weapon Example with Consideration of 1st, 2nd, and 3rd Degree Flash Burn Burns

Adding the consideration of 1st degree burns into the casualty estimate above requires the consideration of individuals exposed to a thermal fluence high enough to result in a 1% TBSA incidence of 1st degree burns, but low enough not to result in a 1% TBSA incidence of 2nd degree burns. For the uniform in the example (12% bare skin and 88% BDU + T-shirt), this would be in the thermal fluence range from 2.16 Cal/cm^2 (90 kJ/m^2) to 2.70 Cal/cm^2 (113 kJ/m^2). Further, these casualties must not have been exposed to 125 cGy of initial ionizing radiation or to 50 kPa of primary blast overpressure, or more, because then they would already have been considered as casualties. In this illustrative scenario, no individual was exposed to less than 4.14 Cal/cm^2 (173 kJ/m^2), thus this casualty estimate does not change with consideration of 1st degree burns.

7. Conclusions and Recommendations

The objective of this study is to describe human response parameters for 1st and 3rd degree burns, which are not already addressed in the NATO CBRN casualty estimation methodology, as described in *AMedP-7.5*. 1st degree burns are painful and noticeable, making them a potential concern as a casualty criterion. 3rd degree burns pose a significant health risk, and a different medical challenge than 1st or 2nd degree burns. Further, burns are potentially prominent contributing factors to casualty estimates for nuclear weapons with yields above approximately 3 KT (at least until blast injury begins to dominate at megaton (MT) yields). This analysis did not consider thermal effects to the eyes (flash blindness or retinal burns), burns from fires secondary to the thermal fluence from the nuclear detonations, or the impact of combined nuclear injuries, such as burns and radiation or burns and blast injuries.

This analysis included several steps to describe human response parameters for 1st and 3rd degree burns:

First, it was necessary to identify the Q_t for 1st and 3rd degree burns to bare skin and various uniform types. The most significant aspect of the definition of Q_t was the specification of a fixed ratio of these values as 0.8 for 1st:2nd degree burns, and 1.53 for 3rd:2nd degree burns.

Second, it was necessary to characterize the burn injuries by severity over time as a function of the insult range. Flash burns on a nuclear battlefield do not happen independently, and a 2nd or 3rd degree burn will not usually occur without surrounding tissue experiencing a more minor burn. An extensive 1st degree flash burn, at greater than 10% TBSA, will also include within the burn area at least a 1% TBSA 2nd degree burn, and would be a more severe injury than just a superficial burn. The 1st degree burn insult range was, therefore, defined as 1–<10% TBSA. For 1st degree burns in the insult range of 1–<10% TBSA, the injury severity was found to be relatively minor, fitting within the definition of "Severity Level 1 (Mild)," and lasting for no more than a week without treatment.

Characterizing 3rd degree burns was more complex. These are more severe burns that involve more organ systems in the body, and 3rd degree flash burns do not occur in the absence of 1st or 2nd degree burns. This analysis found that there was a more narrow set of insult ranges for 3rd degree burns than for 2nd degree burns, but that this more narrow range was encompassed by the already identified 2nd degree burn insult range. Since the NATO CBRN casualty estimation methodology already assumes both types of burns to occur simultaneously, there was no change in the injury severity over time for untreated 2nd and 3rd degree burns in the NATO CBRN casualty estimation methodology.

Third, it was necessary to consider the casualty status with medical treatment. 1st degree burns are routinely treated with “over the counter” medications to ease the pain and moisturize the skin. If this medical care is available on the battlefield (an assumption of the NATO CBRN casualty estimation methodology), the MTOR for 1st degree burns has the casualty returning to duty immediately following treatment.

For 3rd degree burns, because the NATO CBRN casualty estimation methodology already considers 2nd degree burns to include some extent of 3rd degree burns, there was very little change to the MTOR. A literature review did identify, however, the recommendation that “Thermally injured patients are best moved during the first 48 hours after being injured …”[59] This would result in patients with greater than a 5% TBSA 3rd degree burn, or a 20% TBSA 2nd degree burn, becoming CONV (by evacuation to a burn center) within 48 hours. This does not result in any changes to the DOW or RTD estimates, whether for burn injuries or any other CBRN injury or insult.

At the end, this analysis used an illustrative scenario to address the significance (or lack thereof) of considering 1st and 3rd degree flash burns in the casualty estimate. In this scenario, 1st degree burns did not occur in the insult range of 1–<10% TBSA because no individual was estimated to have been exposed in the appropriate thermal fluence range. Changing the time for CONV for casualties with greater than 20% TBSA burns (which include 3rd degree burns of 5% TBSA or greater), did shift 27 persons (out of 816) to CONV on Day 2 from Days 15-30.

The conclusions of this analysis result in three recommendations:

1. While the consideration of 1st degree burns may provide the commander and staff with an indication of the incidence of these burns, on the nuclear battlefield this injury is relatively minor and probably should not be considered significant.

2. 3rd degree burns are not minor, and the medical care requirement is not insignificant, but the expected incidence of 3rd degree burns is already considered in the estimation of burn casualties. It might be of interest to the medical planner to enumerate the number and severity of 3rd degree burns separately, and this analysis demonstrates that possibility, but it does not change the casualty estimate. There should not be a consideration of 3rd degree burns as a separate injury category.

3. The NATO CBRN casualty estimation methodology should be modified to specify CONV for all casualties with 20% TBSA or greater of 2nd degree burns, based on the recommendation to evacuate these casualties to a burn center. Unlike for other CBRN injuries, CONV in this case moves the patients to a higher-level medical facility. A determination is still to be made whether the DOW or RTD estimates for burn injuries or

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[59] *TMM,* 11, 368.

other concurrent CBRN injury or insult should be included in the casualty estimate, as the DOW or RTD would occur out of theater.

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Appendix A.
Illustrations

Figures

Tables

Appendix B.
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Appendix C.
Abbreviations

B	Blast Static Overpressure
BDO	Battledress Overgarment
BDU	Battledress Uniform
Cal/cm^2	Calories per square centimeter
cGy	Centigray
CONV	Convalescent
DOW	Died of Wounds
FD	Final Draft
G-CSF	Granulocyte Colony Stimulating Factor
HoB	Height of Burst
IND	Improvised Nuclear Devices
KIA	Killed In Action
kJ/m^2	Kilojoules per square meter
kPa	Kilopascals
KT	Kiloton equivalent of TNT
LIBN	Light Infantry Battalion Task Force
MT	Megaton equivalent of TNT
MTOR	Medical Treatment Outcome Reporting Table
Qn50	Fluence required to produce a 50-percent incidence of nth-degree burn
Q_t	Threshold Fluence
R	Radiation
RTD	Returned to Duty
T	Thermal Exposures
TBSA	Total body surface area
TMM	*Textbook of Military Medicine*
WIA	Wounded in Action

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REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE (DD-MM-YY)	2. REPORT TYPE	3. DATES COVERED (From – To)
XX-03-2017	Final	

4. TITLE AND SUBTITLE	5a. CONTRACT NO.
Parameters for Estimation of Casualties from First and Third Degree Flash Burns	HQ0034-14-D-0001
	5b. GRANT NO.
	5c. PROGRAM ELEMENT NO(S).
6. AUTHOR(S)	5d. PROJECT NO.
Carl A. Curling Samantha Todd	5e. TASK NO. CA-6-3079
	5f. WORK UNIT NO.
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Institute for Defense Analyses 4850 Mark Center Drive Alexandria, VA 22311-1882	8. PERFORMING ORGANIZATION REPORT NO. IDA Paper P-8374 IDA Log H 17-000154
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Army Office of The Surgeon General/MEDCOM G-37 Force Management DHHQ 7700 Arlington Blvd. Falls Church, VA 22042-5143	10. SPONSOR'S / MONITOR'S ACRONYM(S) OTSG 11. SPONSOR'S / MONITOR'S REPORT NO(S).

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This document describes the continued extension of the CBRN Casualty estimation methodology to include 1st and 3rd degree flash burns. Flash burns result from the initial thermal pulse from the nuclear weapon detonation. The thermal pulse from a detonation lasts from a fraction of a second to several seconds in duration (increasing with yield), and is assumed to result in exposure to the exposed skin on the body (typically not more than 50% of the body surface area). This analysis identified the threshold fluenc values (Q_t) for 1st and 3rd degree burns to bare skin and various uniform types.
The 1st degree burn insult range is 1–<10 percent of the total body surface area (%BSA) because a 1st degree flash burn greater than 10 % BSA will also include at least a 1 %BSA 2nd degree burn,. For 1st degree burns in the insult range of 1–<10 %BSA, the injury severity was found to be relatively minor, fitting within the definition of "Severity Level 1 (Mild)," and lasting for no more than a week without treatment. There was no change in the characterization of burn injury severity over time when considering both 2nd and 3rd degree burns. 1st degree burns are routinely treated with "over the counter" medications to ease the pain and moisturize the skin, and the casualty returns to duty immediately following treatment, on Day 2. For 3rd degree burns, patients with greater than a 5 %BSA 3rd degree burn, or a 20 %BSA 2nd degree burn, becoming CONV (by evacuation to a burn center) at 48 hours. There are no changes to the DOW or RTD estimates, whether for burn injuries or any other CBRN injury or insult.

15. SUBJECT TERMS

Burns, Treatment, radiation, chemical, biological, radiological, nuclear, CBRN

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NO. OF PAGES	19a. NAME OF RESPONSIBLE PERSON MAJ Thomas Rezentes
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (Include Area Code)
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