An Analysis of the Fireline Production Rates Applied to Aerial Retardant Drops Contained in MNIAAPC

National Airtanker Study - Phase 2
November, 1995

Since 1979, the Forest Service's Initial Attack Assessment Model (MNIAAPC) has used a formula to determine the amount of fireline produced by aerial fire retardant drops. The amount of fireline produced by a drop is based on the use of long term fire retardant and varies by the number of gallons in the drop as well as the National Fire Danger Rating System (NFDRS) fuel model. The NFDRS fuel models are described below:

Closest FBPS Fuel Model	NFDRS Fuel Model	NFDRS Fuel Model Description
1	A	Grass, Short
4	B	Chaparral
2	C	Grass w/Pine
7	D	Southern Rough
9	E	Hardwoods (Winter)
5,6	F	Intermediate Brush
10	G	Short Needle, Heavy
8	H	Short Needle, Light
13	I	Slash, Heavy
12	J	Slash, Medium
11	K	Slash, Light
2	L	Grass, Perennial
3	N	Sawgrass
4	O	High Pocosin
9	P	Southern Pine Plantation
6	Q	Alaska Black Spruce
8	R	Hardwoods (Summer)
1	S	Tundra
6	T	Western Woody Shrub
9	U	Pine Litter

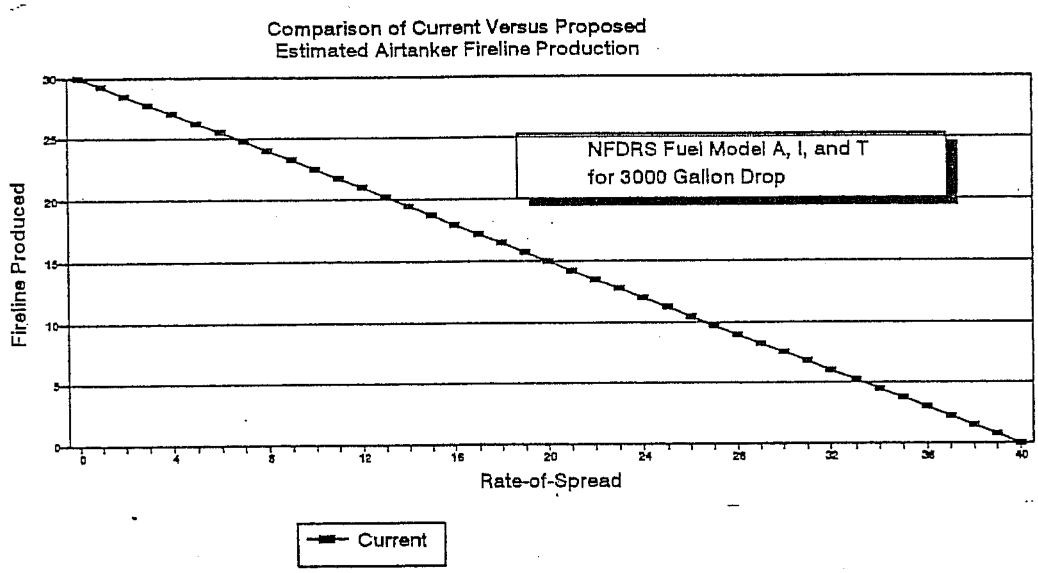
The formula used is:

$$\text{Chains of line} = (\text{Gallons in Drop})/100 \ * \ \text{Production Factor}$$

where the production factor is 1.0 for NFDRS fuel models A, L and T, is 0.6 for NFDRS fuel models C, N, S, and U and is 0.4 for all the rest of the NFDRS fuel models. The following chart gives the chains of fireline built per drop for several sizes of airtankers.

Gallons Dropped	Fuel Models A, L, T	Fuel Models C, N, S, U	Fuel Models Others
3000 Gallons	30 chains	18 chains	12 chains
2450 Gallons	25 chains	16 chains	10 chains
2000 Gallons	20 chains	12 chains	8 chains

To model the effectiveness of retardant drops as it relates to rate of fire spread, the amount of fireline produced is reduced linearly from its maximum value described. Maximum fireline production is assumed when the rate of fire spread is equal to one chain/hour. The fireline production rate is then decreased linearly so that the fireline production rate is zero when the rate of fire spread is equal to forty chains per hour or greater. The graph on this page shows this relationship for a 3000 gallon drop in fuel models A, L or T.



To insure that fire retardant drops are used in conjunction with other firefighting forces such as engine crews, helitack crews, hand crews, and dozers, these forces must arrive within 60 minutes of a fire retardant drop when the flame length on the modelled fire is less than two feet or the IAA will assume the fire retardant drop was ineffective. If the flame length on the modeled fire is greater than two feet, this time limit is reduced to 30 minutes.

The amount of retardant that is need by to retardant a fire is dependent on fuel type (model). Rothermel and Philpot (1975) did research documented in column 1 of the following table. The fuel models are from the 1972 version of NFDRS. The fuel models that follow were added to the NFDRS in 1978.

George in 1992 was published Research Note INT-400 which provided information on the amount of fireline that could be produced by coverage level. For explanation purposed, assume a 3000 gallon retardant drop. The following is the amount of fireline in chains based on coverage level:

<------------------------------Coverage Level-------------------------->						
0.5	1.0	2.0	3.0	4.0	6.0	8.0
49 ch.	31 ch.	21 ch.	17 ch.	14 ch.	9 ch.	5 ch.

Based on the coverage levels recommended by Rothermel and Philpot (1975), column 2 indicates the amount of fireline that could be produced. In both columns 1 and 2, no canopy interception is considered.

In column 3, an estimate is given if the expected canopy coverage in the fuel model would be greater than 40% If so, information contained in a study by Honeywell (1973) allows for a reduction in fireline produced based on tree canopy interception. An estimate of this net result is in column 4. Information in columns 3 and 4 for the 1978 NFDRS fuel models is estimated from fuel model

NFDRS Fuel Model	1 Roth.[1] and Phil. 1975	2 INT-400[2] Table 3 Chains of Line	3 40% or Greater Canopy Coverage	4 3000 G.[3] Estimated Fireline Chains	5 INT-400 Coverage Level gpc	6 INT-400 Chains of Fireline in Chains	7 IAA Chains of Fireline in Chains
	No Canopy	No Canopy	Yes/No	Canopy	Canopy	Canopy	Canopy
A	.63	45	No	45	1.0	31	30
B	8.33	5	No	5	>6.0	5	12
C	1.98	21	Yes	19	2.0	21	18
D	6.00[4]	9	Yes	8	6.0	9	12
E	2.65	18	Yes	17	2.0	21	12
F	2.16	21	No	21	3.0	17	12
G	4.38	12	Yes	11	4.0	14	12
H	2.24	20	Yes	19	2.0	21	12
I	9.60	5	No	5	>6.0	5	12
J	5.63	7	No	7	>6.0	5	12
K	1.98	21	Yes	19	3.0	17	12
L	2.60	19	No	19	1.0	31	30
<u>Fuel Models Added in 1978</u>				[5]			
N			No	21	3.0	17	18
O			No	5	>6.0	5	12
P			Yes	17	2.0	21	12
Q			Yes	8	6.0	9	12
R			Yes	17	2.0	21	12
S			Yes	45	1.0	31	18
T			No	19	3.0	17	30
U			Yes	19	2.0	21	18

descriptions as the research by Rothermel and Philpot was done prior to the time these fuel models were created.

George via personal communication has indicated that the recommended coverage levels in column 5 were developed considering both fuel model need as well as reduction for crown interception. Data also used included extensive drop testing by different aircraft. In addition, the lowest coverage level recommended for application is coverage level 1.

Table 3 from RN-INT-400 was again used to develop column 6. This column contains an estimate of the fireline for a 3000 gallon retardant drop based in the recommended coverage level in column 5. Note that even though Table 3 assumes a no canopy situation, changes in coverage level to compensate for crown

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[1] - Rothermel, Richard C. and C. W. Philpot. Reducing Fire Spread in Wildland Fuels. A Reprint from: Experimental Methods in Fire Research. 1975. Proceedings of the Meeting to Honor Clay Preston Butler, Stanford Research Institute, May 9-10, 1974. P. 369-403. Also documented in a report by Honeywell called Development of User Guidelines for Selected Retardant Aircraft, Final Report Contract No. 26-3332 (February 15, 1975).

[2] - From Table 3 in: George, Charles W. Improving the Performance of Fire Retardant Delivery Systems on Fixed-Wing Aircraft. USDA-FS. Intermountain Research Station Research Note INT-400. February 1992. 12p.

[3] - High Altitude Retardant Drop Mechanism Study, Final Report, Volume II, Capture of Retardants in Vertical Fuels. Honeywell to USDA-FS, Intermountain Forest and Range Experiment Station. April 30, 1973. 91p. Information Presented Used to Assume The Following Percent Loss in Canopy: Coverage Level 1 -20%; Coverage Level 2 -10%; Coverage Level 3+ -5%;

[4] - Assumed Based on INT-400 Since Fuel Model Was Not Defined in 1972 NFDRS

[5] - Assumption Based on Similaries From Fuel Models A-L.

interception allow for estimation of fireline length in a canopied situation.

Column 7 gives a listing of the amount of fireline predicted using factors in the current version of MNIAAPC. This information is repeated in columns 14 and 15 below. To determine IAA Reduction Factors (column 9) based on column 5 and 6 data, the ratio of the entry in column 5 was divided by 30 since this data was developed assuming a 3000 gallon retardant drop (see formula on page 1). For rounding purposes, the 31 chains of line divided by 30 was rounded down to 1.0. These ratios hold close to the stated values except for coverage levels 2 or less AND with drops less than 1200 gallons.

	8	9	10	11	12	13	14	15
NFDRS Fuel Model	Prop. Coverage Level	Prop. IAA Reduction Factor	Maximum ROS Increased to 80 c/h Yes/No	Chains of Fireline from 3000 Gal. Drop	Percent Change in Fireline Old to Proposed	Current Coverage Level	Current IAA Reduction Factors	Chains of Fireline from 3000 Gal. Drop
A	1	1.0	Yes	30	0%	1	1.0	30
L	1	1.0	Yes	30	0%	1	1.0	30
S	1	1.0	Yes	30	+68%	1	0.6	18
C	2	0.7	No	21	+17%	3	0.6	18
H	2	0.7	No	21	+75%	5	0.4	12
R	2	0.7	No	21	+75%	5	0.4	12
E	2	0.7	No	21	+75%	5	0.4	12
P	2	0.7	No	21	+75%	5	0.4	12
U	2	0.7	No	21	+17%	3	0.6	18
T	3	0.6	Yes	18	-40%	1	1.0	30
N	3	0.6	No	18	0%	3	0.6	18
F	3	0.6	No	18	+50%	5	0.4	12
K	3	0.6	No	18	+50%	5	0.4	12
G	4	0.5	No	15	+25%	5	0.4	12
D	6	0.3	No	9	-25%	5	0.4	12
Q	6	0.3	No	9	-25%	5	0.4	12
B	6+ (8)	0.2	No	6	-50%	5	0.4	12
O	6+ (8)	0.2	No	6	-50%	5	0.4	12
J	6+ (8)	0.2	No	6	-50%	5	0.4	12
I	6+ (8)	0.2	No	6	-50%	5	0.4	12

Column 11 contains as estimate of the expected fireline length using the proposed reduction factors. Column 12 gives an estimate of the change in expected fireline from new to current. This change is based only on the reduction factors.

A concern has been expressed that the linear reduction in fireline production from 0 ch/hr to 40 ch/hr does not allow the display of airtanker effectiveness at rates of spread greater than 40 ch/hr. Professional experience indicates that is number might be better set at 80 ch/hr. for fuel models that represent grass and some sagebrush type fuel models such as NFDRS fuel models A, L, S and T. Hence it is also proposed that is change be made. In column 10, a yes indicates the maximum ROS of 80 chains per hour criteria be applied.

Resultant examples of how these collective changes would effect fireline length produced are contained on the following graphs.

Reprinted from: Experimental Methods in Fire Research. 1975. Proceedings of the Meeting to Honor Clay Preston Butler, Stanford Research Institute, May 9-10, 1974
P. 369-403

REDUCING FIRE SPREAD IN WILDLAND FUELS

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Missoula, Montana

Table 6.--Maximum useful retardant concentration

Fuel	Fuel loading <3-inch diameter	Total gpc
	Tons/acre	
Short grass	0.75	0.60
Tall grass	3.00	2.60
Brush	3.50	1.80
Chaparral	16.00	10.00
Timber, Grass & Understory	4.00	2.60
Timber litter	5.00	1.60
Timber litter & Understory	12.00	5.00
Hardwood litter	3.50	2.80
Logging slash, light	7.60	2.60
Logging slash, medium	34.50	7.50
Logging slash, heavy	58.00	13.00

DEVELOPMENT OF USER GUIDELINES for SELECTED RETARDANT AIRCRAFT

Final Report
Contract No. 26-3332
to

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
OGDEN, UTAH 84401

A REPORT OF RESEARCH PERFORMED UNDER THE AUSPICES OF THE INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION, OGDEN, UTAH

Pg 15 - 23

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Table 1. Values of the Maximum Useful Retardant Concentration

Fuel	Total gpc[a]	Total gpc[b]	Related Fire Danger Rating Model[c]
Short Grass	0.69	0.63	A
Tall Grass	2.60	2.60	D
Brush	1.80	2.16	F
Chaparral	10.00	8.33	B
Timber, Grass and Understory	2.60	1.98	C
Timber Litter	1.60	2.24	H
Timber Litter and Understory	5.00	4.38	G
Hardwood Litter	2.80	2.65	E
Logging Slash, Light	2.60	1.98	-
Logging Slash, Medium	7.50	5.63	I
Logging Slash, Heavy	13.00	9.60	-

a Reducing Fire Spread in Wild Land Fuels, Rothermel, R. C., and Philpot, C., Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah, July 1974 (Ref. 5)

b Letter, Rothermel to Swanson, 17 October 1974 (Ref. 6) Considers effect of Retardant Film Thickness

c National Fire Danger Rating System, Deeming et al, USDA Forest Service Research Paper RM-84, February 1972, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado (Ref. 4)

HIGH ALTITUDE RETARDANT DROP MECHANISM STUDY

Final Report
Volume II

CAPTURE OF RETARDANTS IN VERTICAL FUELS

to

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
OGDEN, UTAH 84401

A report of research performed under the auspices of the Intermountain Forest and Range Experiment Station

Honeywell

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HOPKINS, MINNESOTA 55343

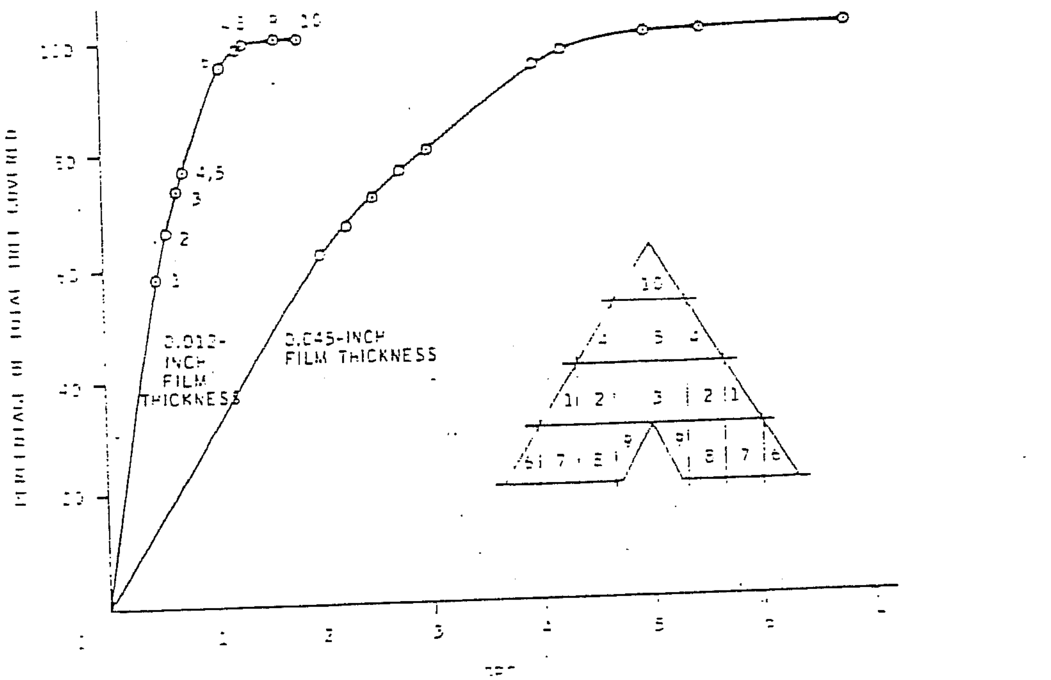


Figure A1. Percent Covered versus Application Rate (Two Film Thicknesses)

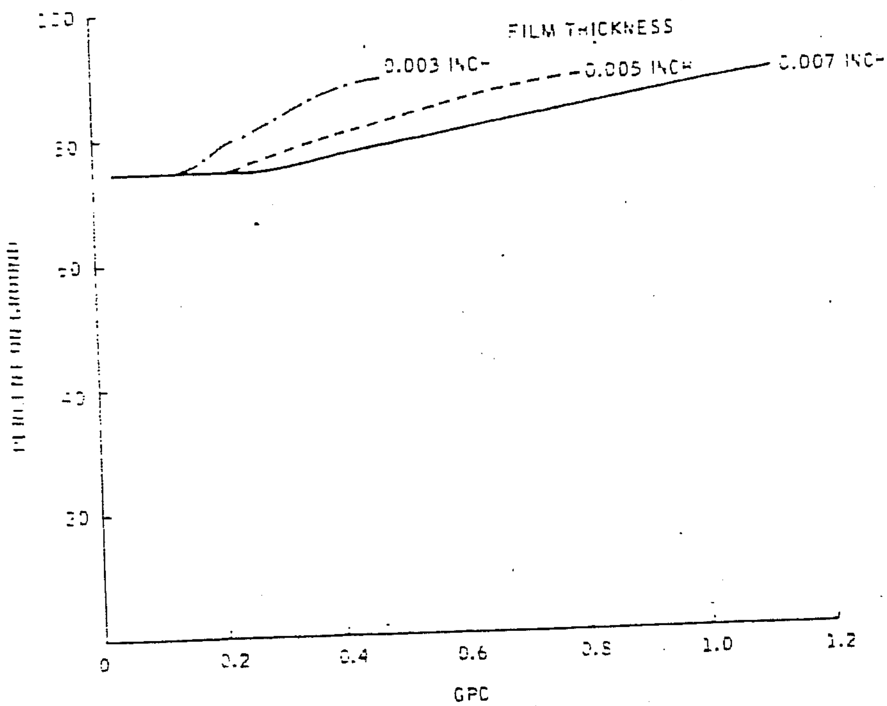


Figure A2. Percent on Ground versus Application Rate (Three Film Thicknesses)

From RN - INT-400

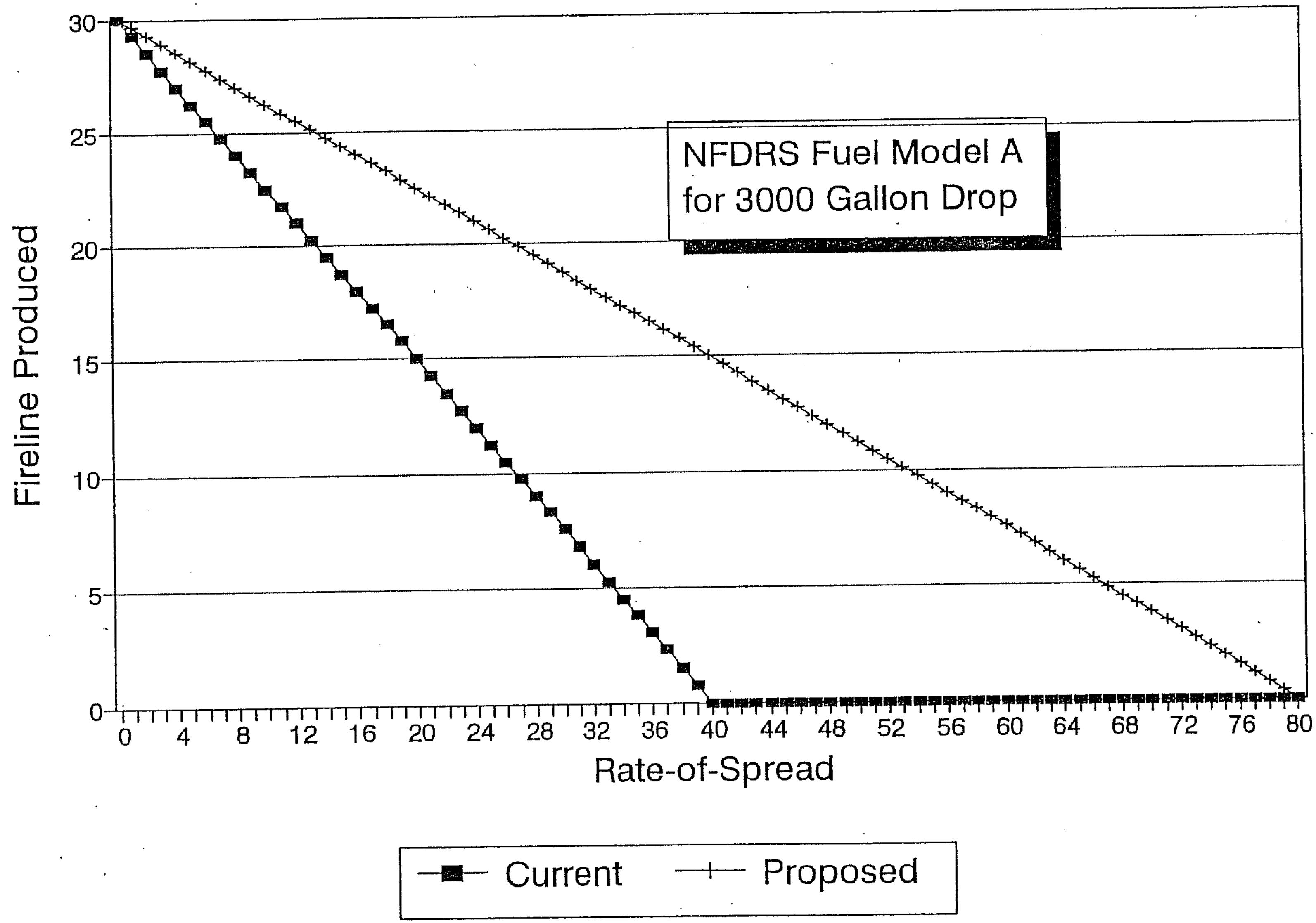
Table 3—Line production values in feet for improved airtankers as a function of coverage level and airtanker volume. (Numbers in parentheses are line length/100 gallons)

Volume	Coverage level 0.5	1	2	3	4	6	8
Gallons	*gpc*						
800	2,246 (281)	1,114 (139)	526 (66)	311 (39)	189 (24)	38 (5)	0 (0)
1,000	2,337 (234)	1,202 (120)	607 (61)	384 (38)	255 (26)	90 (9)	0 (0)
1,200	2,429 (202)	1,289 (107)	687 (57)	458 (38)	321 (27)	142 (12)	9 (1)
1,400	2,520 (180)	1,377 (98)	768 (55)	531 (38)	387 (28)	194 (14)	46 (3)
1,600	2,611 (163)	1,465 (92)	848 (53)	604 (38)	454 (28)	245 (15)	84 (5)
1,800	2,702 (150)	1,552 (86)	929 (52)	678 (38)	520 (29)	297 (17)	121 (7)
2,000	2,794 (140)	1,640 (82)	1,009 (50)	751 (38)	586 (29)	349 (17)	158 (8)
2,200	2,885 (131)	1,728 (79)	1,090 (50)	824 (37)	652 (30)	400 (18)	196 (9)
2,400	2,976 (124)	1,815 (76)	1,170 (49)	897 (37)	718 (30)	452 (19)	233 (10)
2,600	3,068 (118)	1,903 (73)	1,251 (48)	971 (37)	784 (30)	504 (19)	270 (10)
2,800	3,159 (113)	1,991 (71)	1,331 (48)	1,044 (37)	850 (30)	556 (20)	308 (11)
3,000	3,250 (108)	2,078 (69)	1,411 (47)	1,117 (37)	916 (31)	607 (20)	345 (12)

Fuel Model NFDRS	FB	Coverage Level (gal/100 ft^2)	Flow Rate Range (gal/s)	Description
A,L,S	1	1	100-150	Annual & Perennial Western Grasses; Tundra
C H,R E,P,U	2 8 9	2	151-250	Conifer with Grass Shortneedle Closed Conifer; Summer Hardwood Longneedle Conifer; Fall Hardwood
T N F K	2 3 5 11	3	251-400	Sagebrush with Grass Sawgrass Intermediate Brush (green) Light Slash
G	10	4	401-600	Shortneedle Conifer (heavy dead litter)
Error *D F,O	*7 6	6	601-800	Southern Rough Intermediate Brush (cured); Alaska Black Spruce
B,O J I	4 12 13	Greater than 6	Greater than 800	California Mixed Chaparral; High Pocosin Medium Slash Heavy Slash

Figure 7—Retardant flow rate range and coverage level recommended for NFDRS fuel and fire behavior models.

Comparison of Current Versus Proposed Estimated Airtanker Fireline Production



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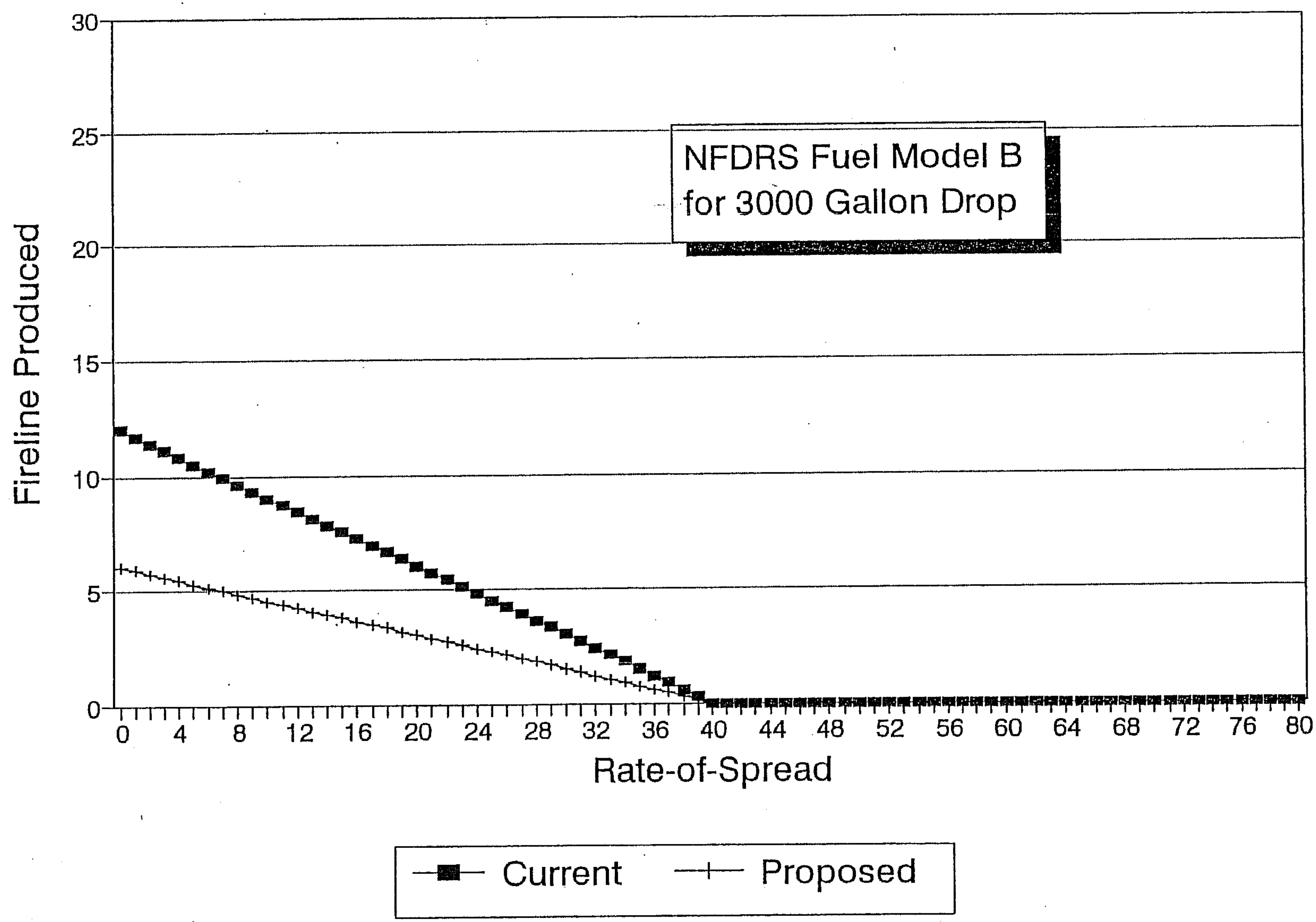

Comparison of Current Versus Proposed
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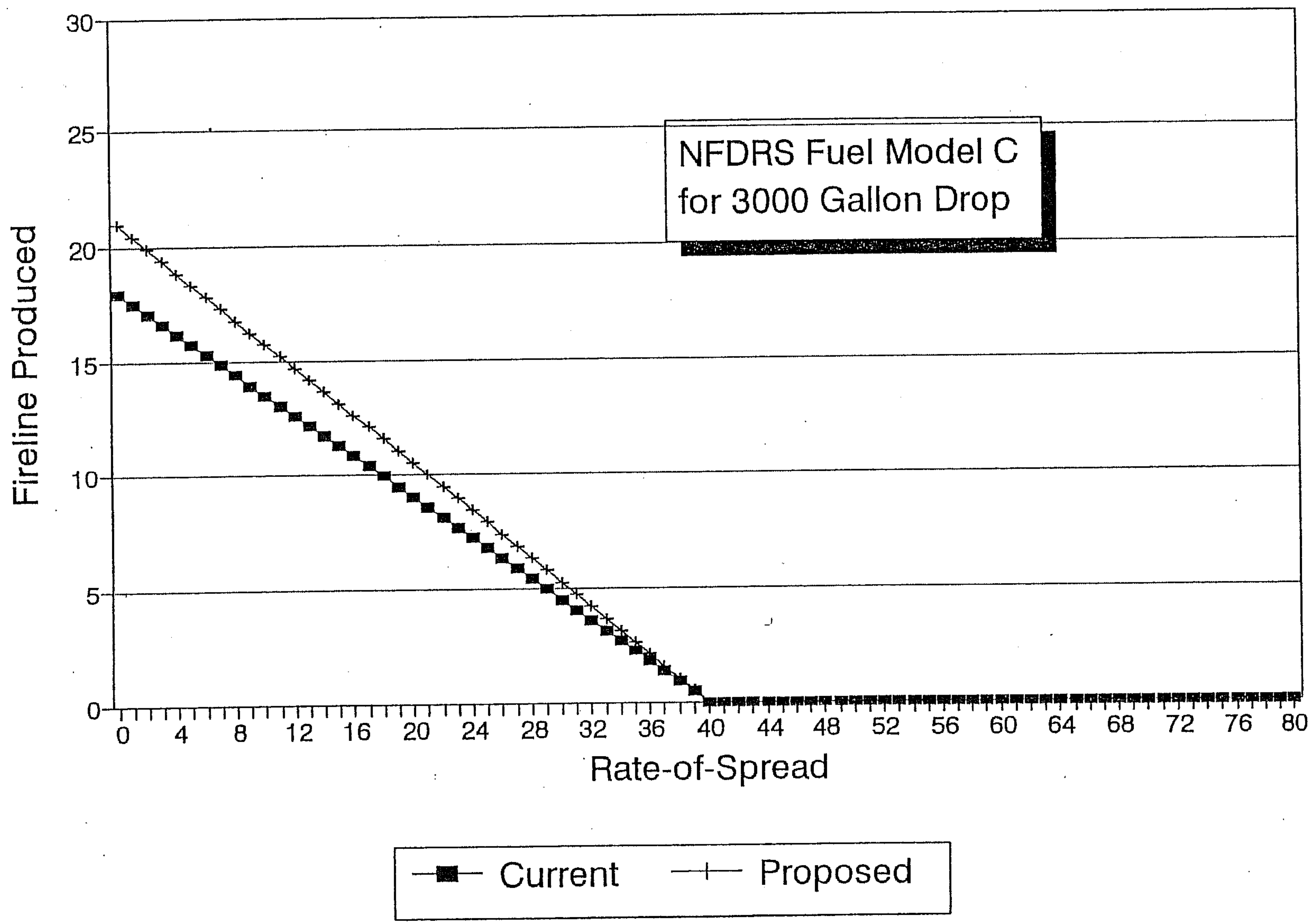

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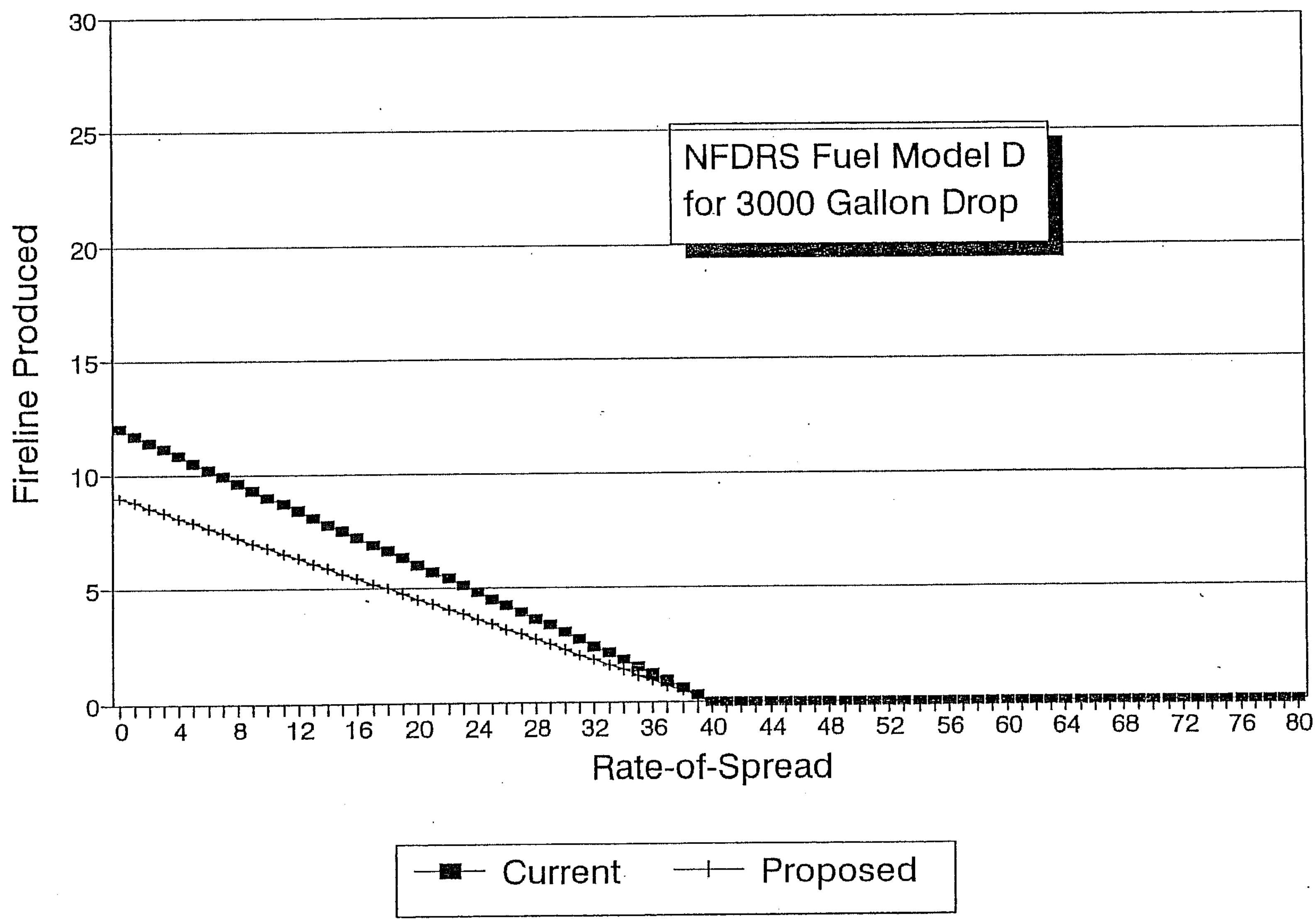

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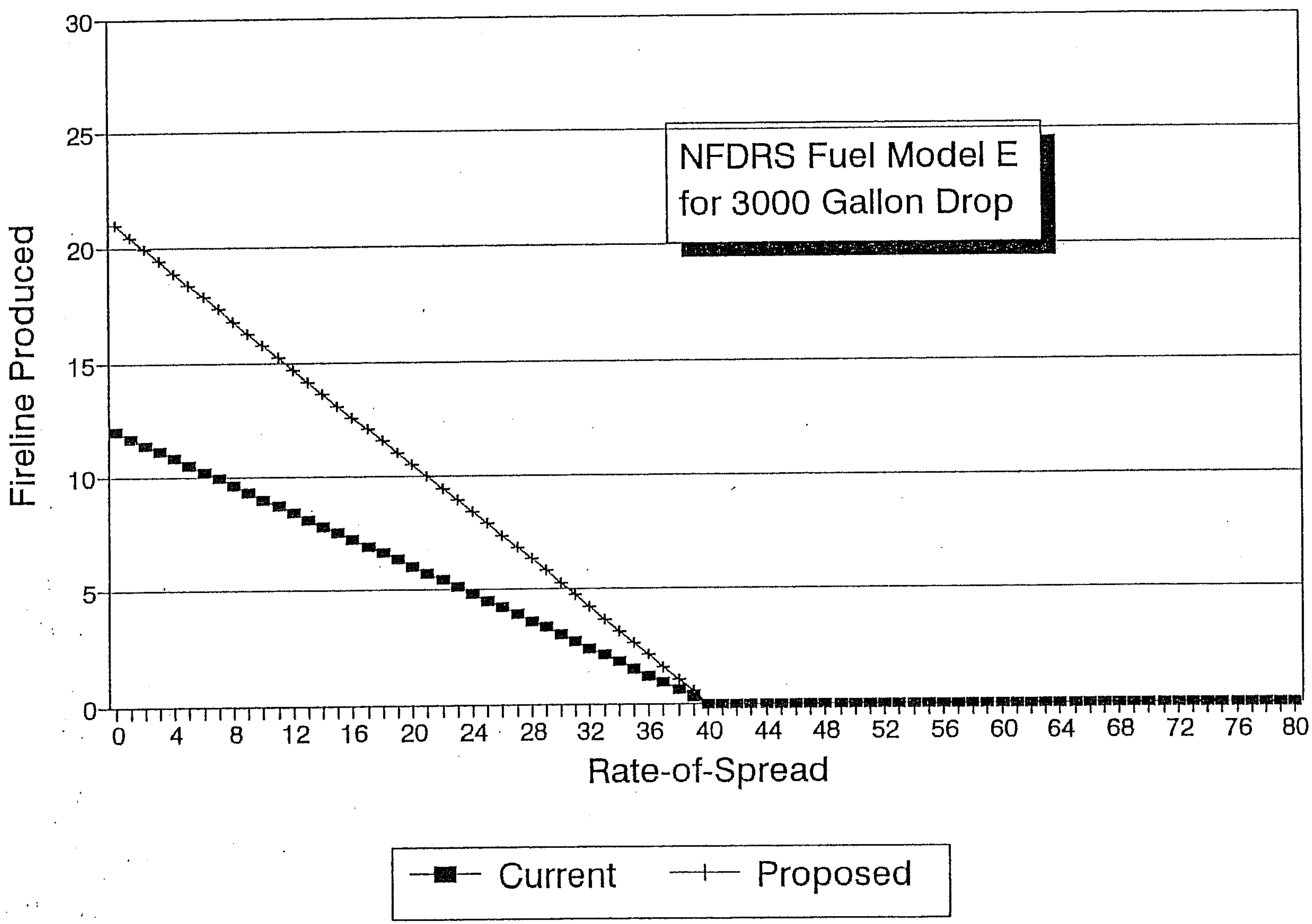

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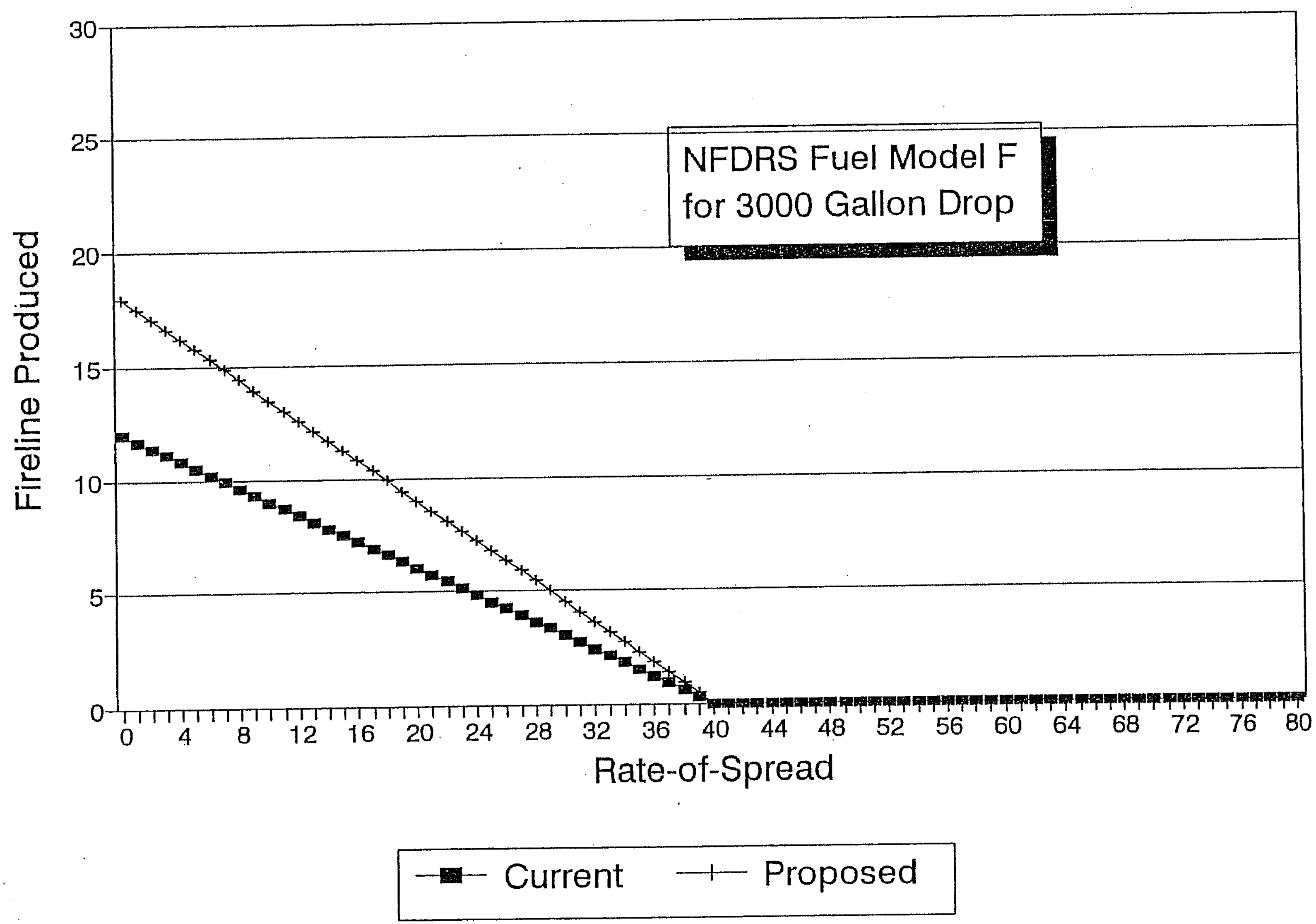
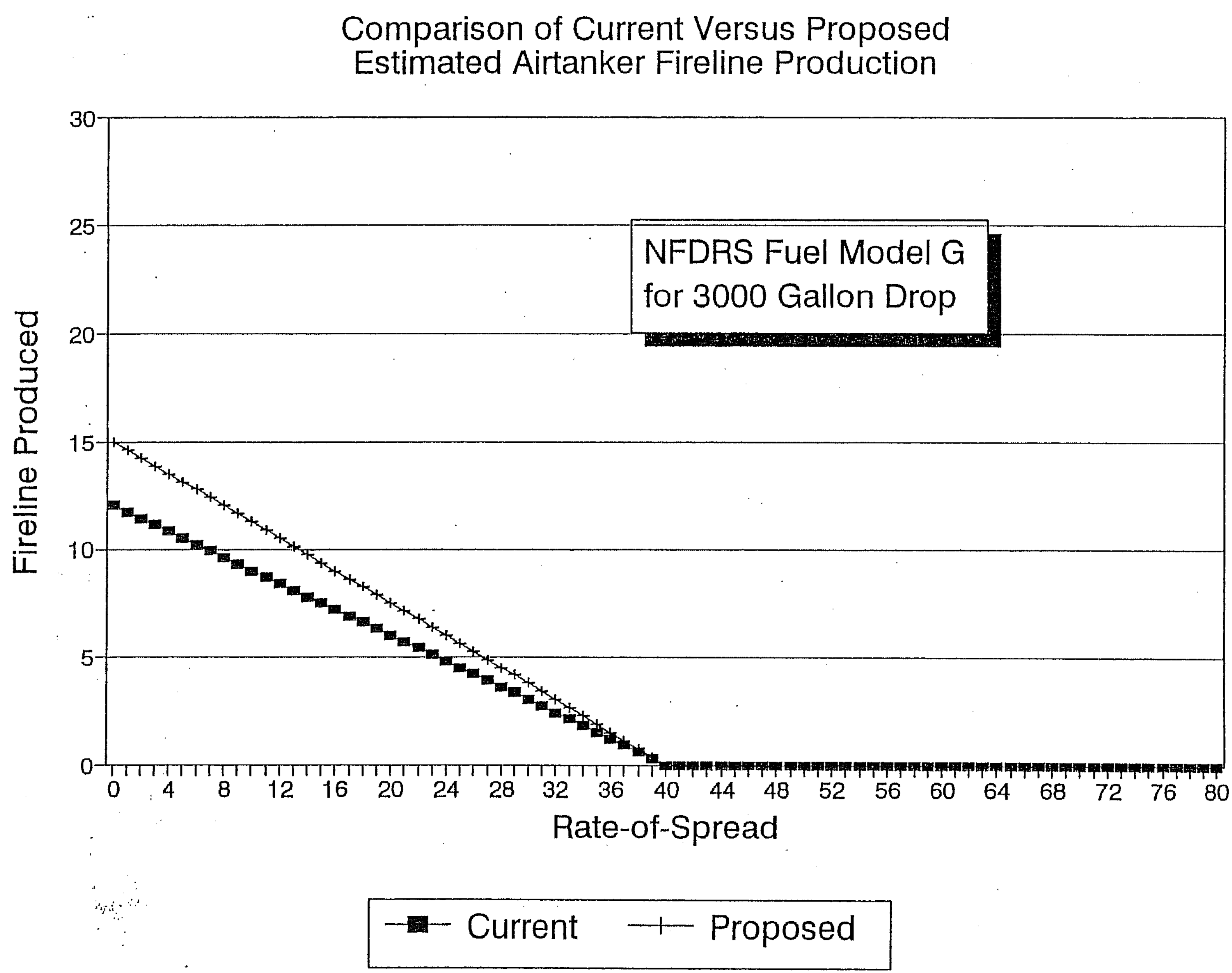
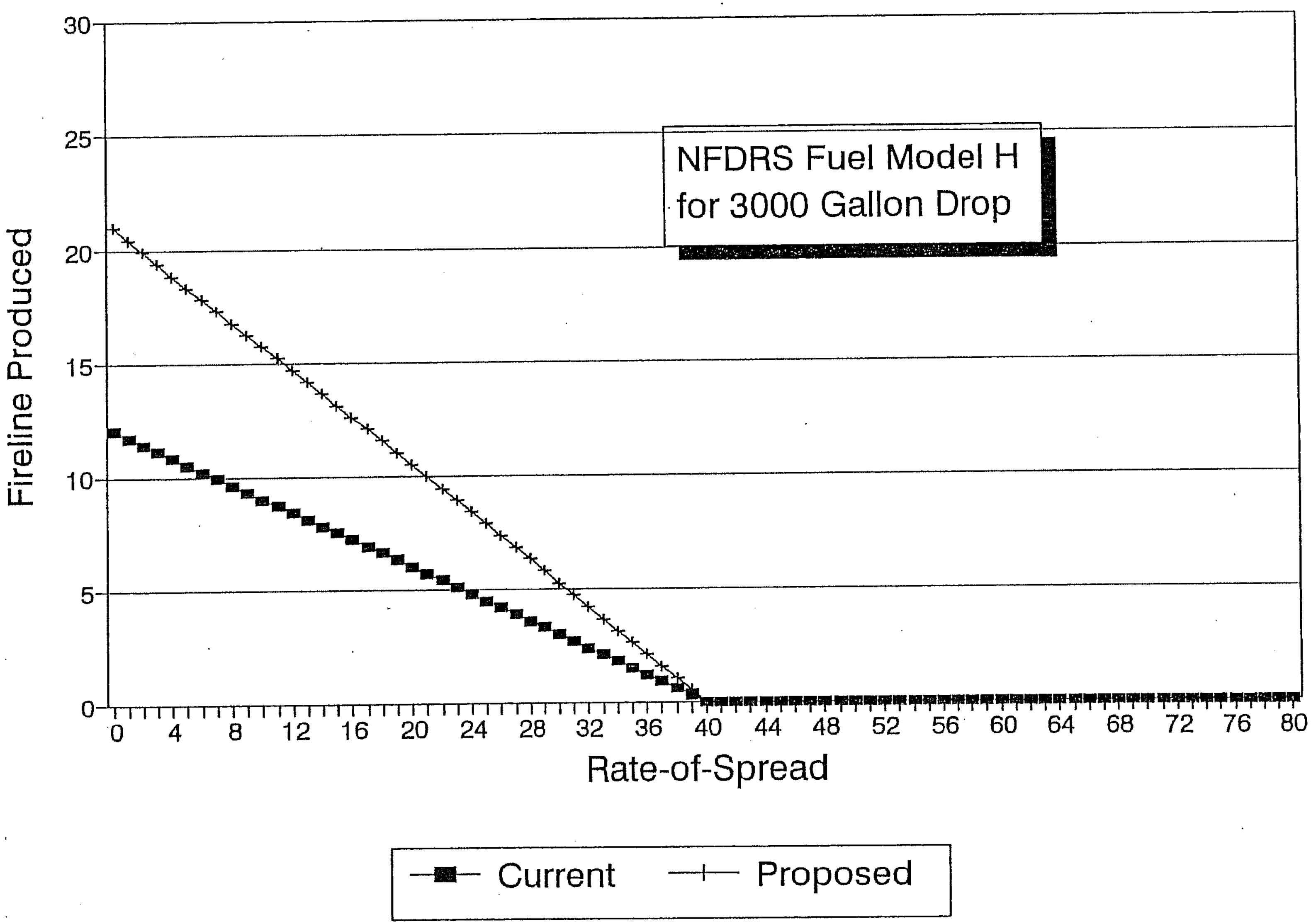



Comparison of Current Versus Proposed
Estimated Airtanker Fireline Production
NFDRS Fuel Model G
for 3000 Gallon Drop
Fireline Produced
30
25
20
15
10
5
0
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
80
Rate-of-Spread
Current
Proposed

Comparison of Current Versus Proposed Estimated Airtanker Fireline Production



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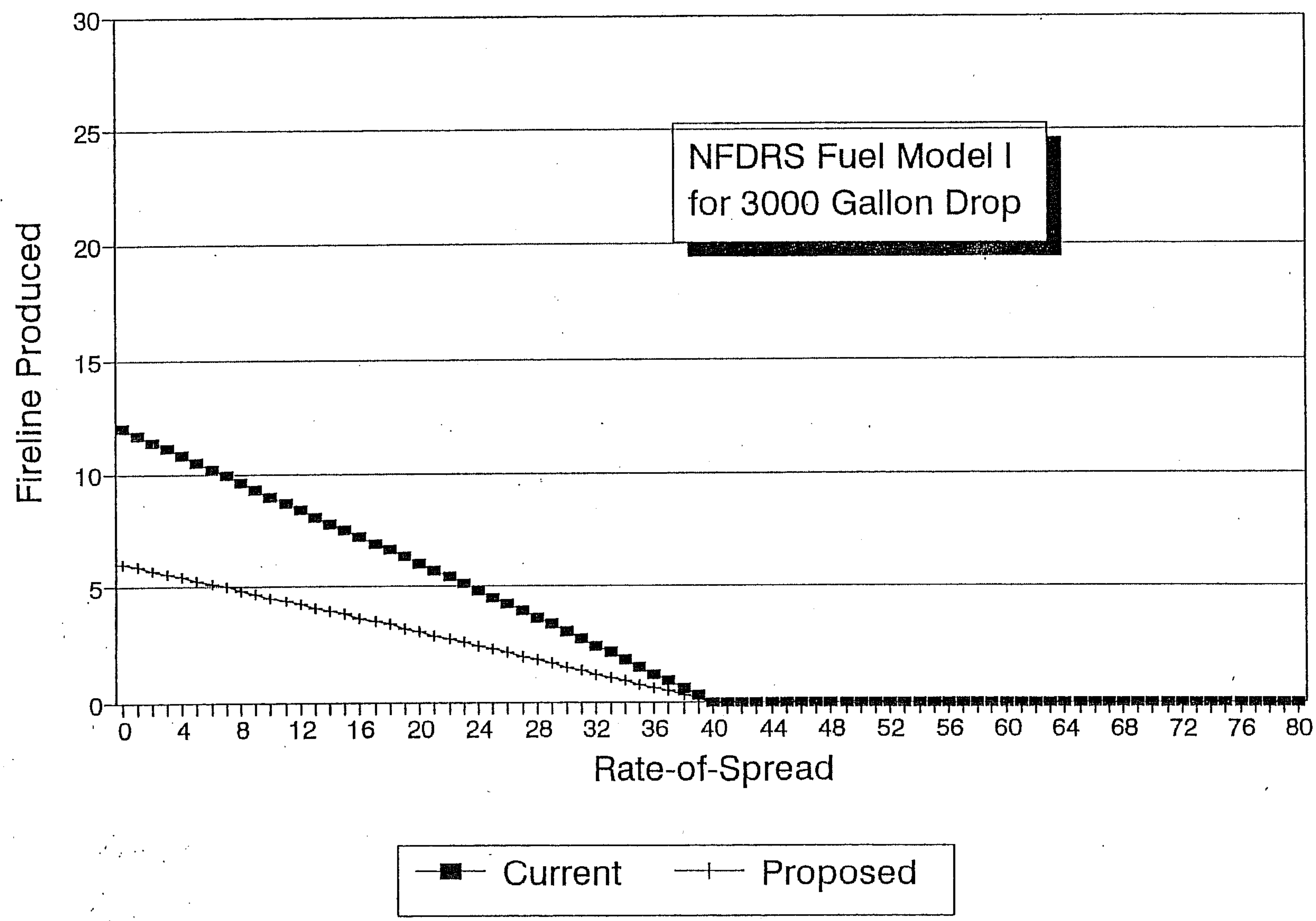

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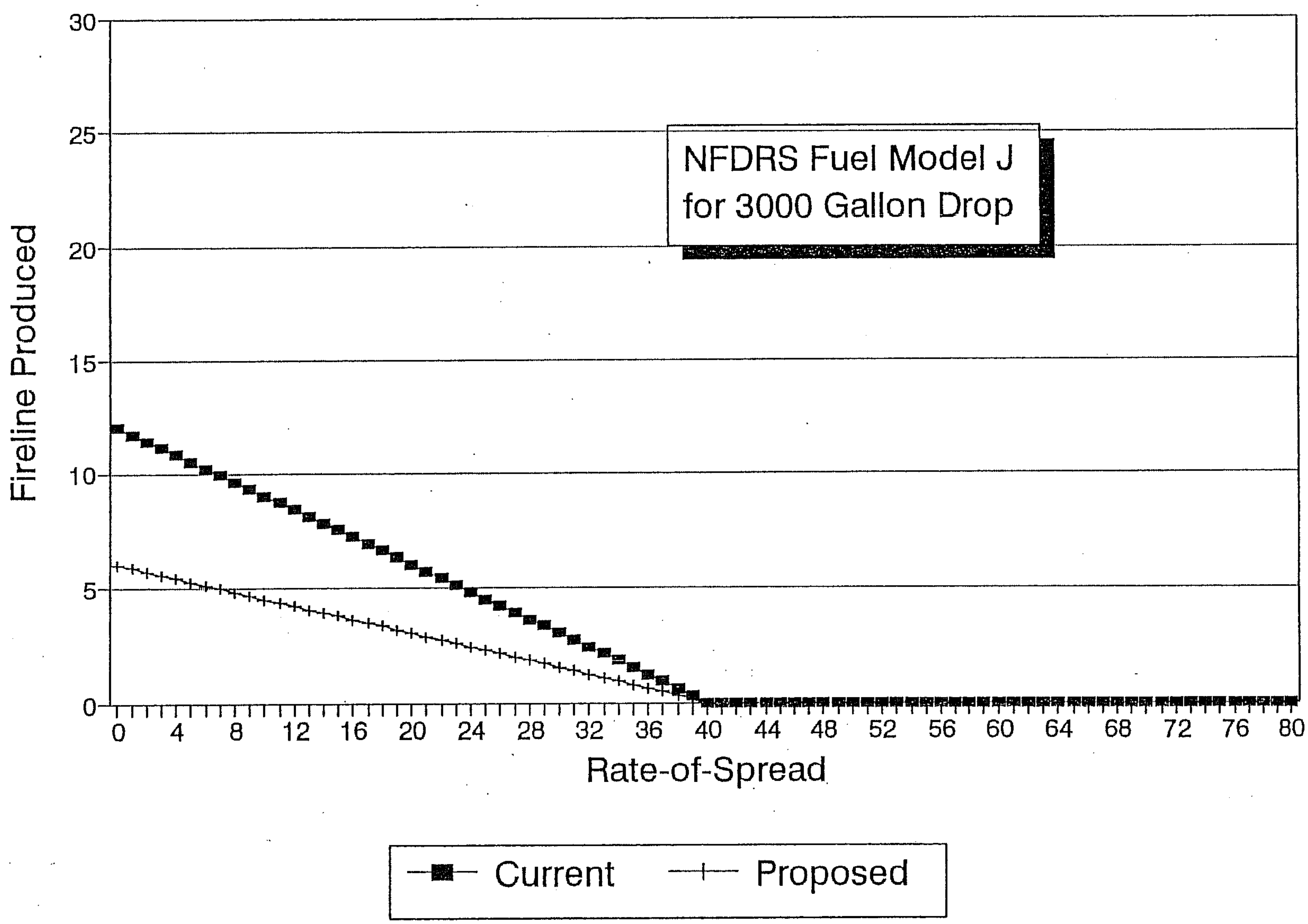

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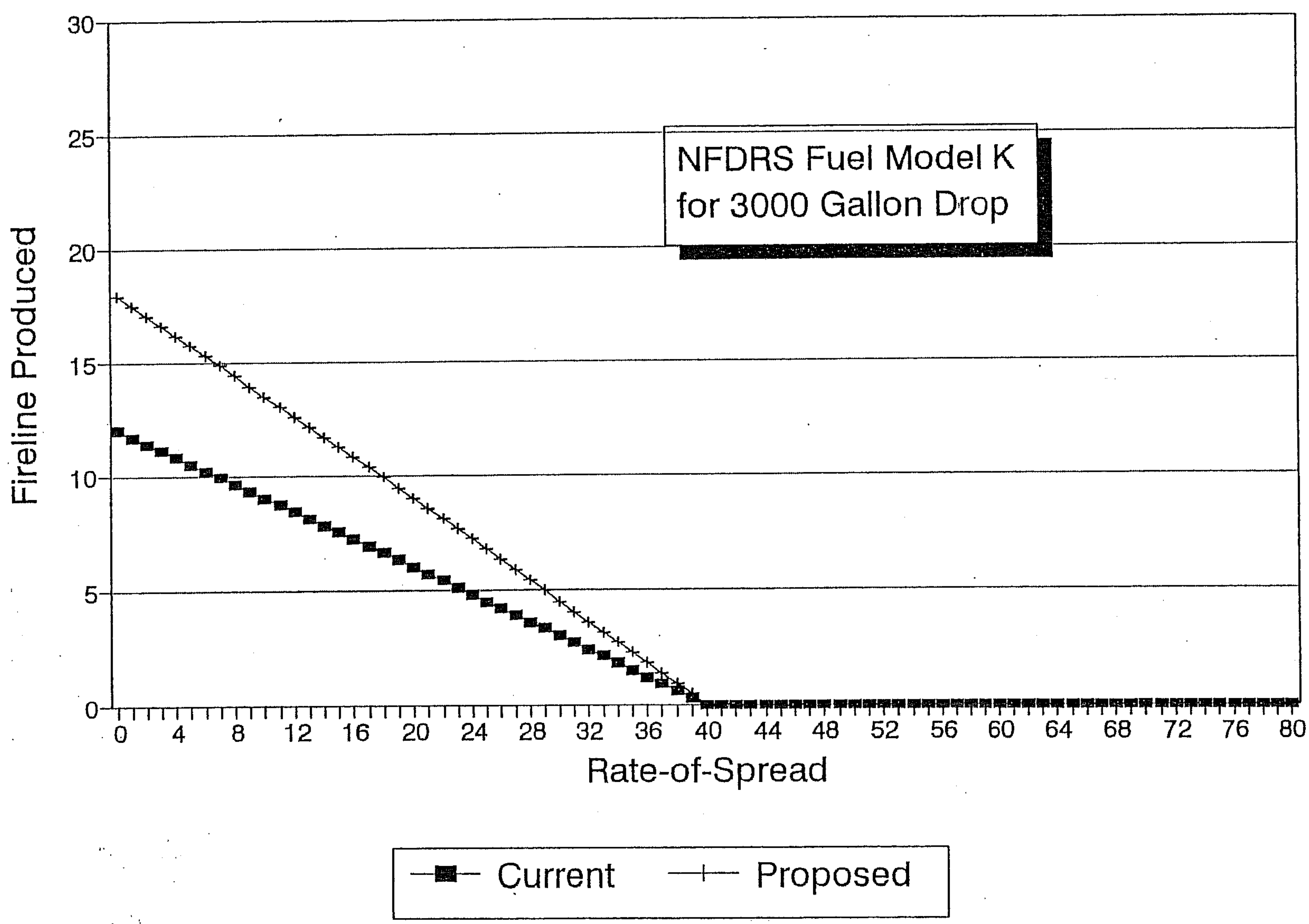

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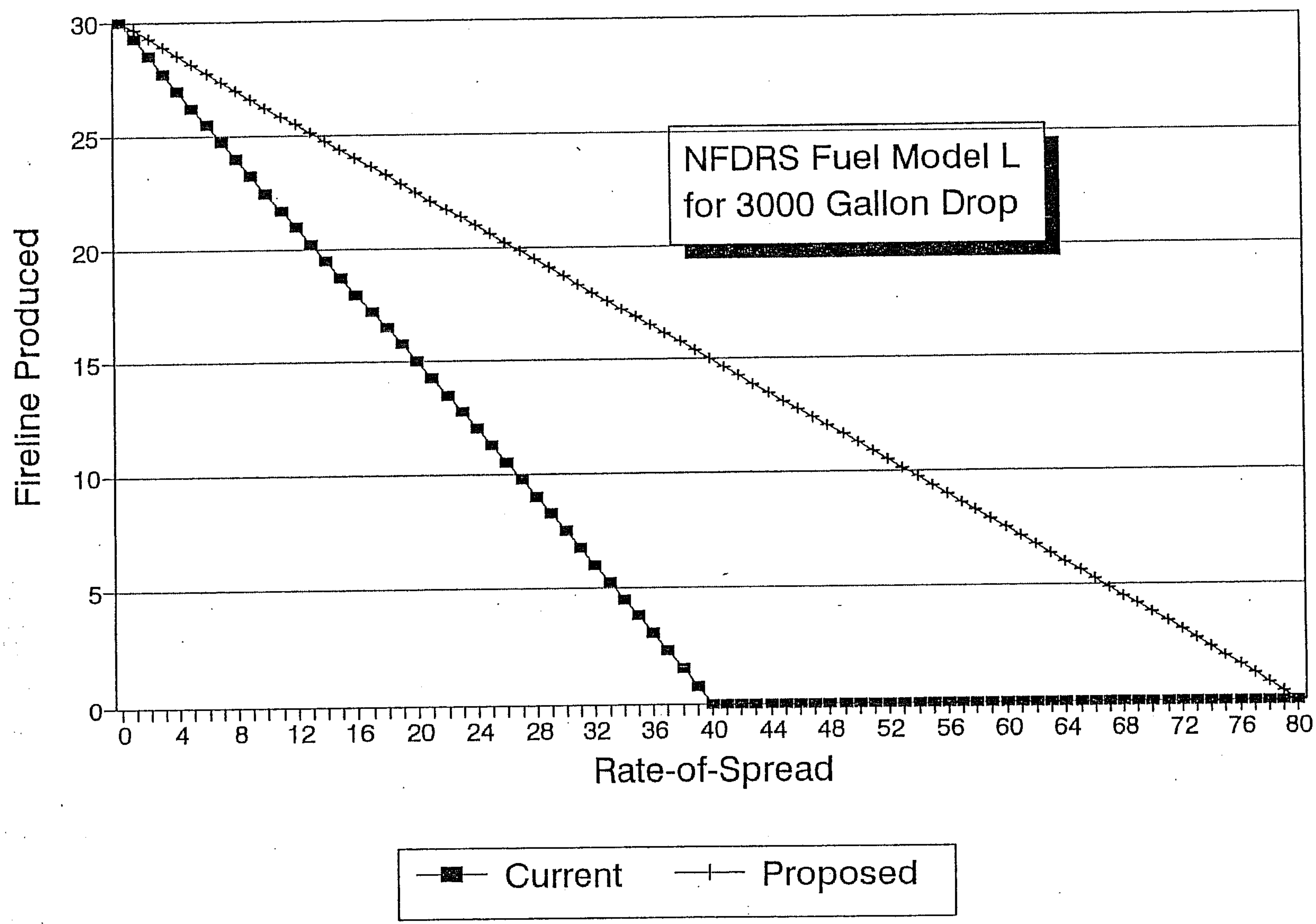

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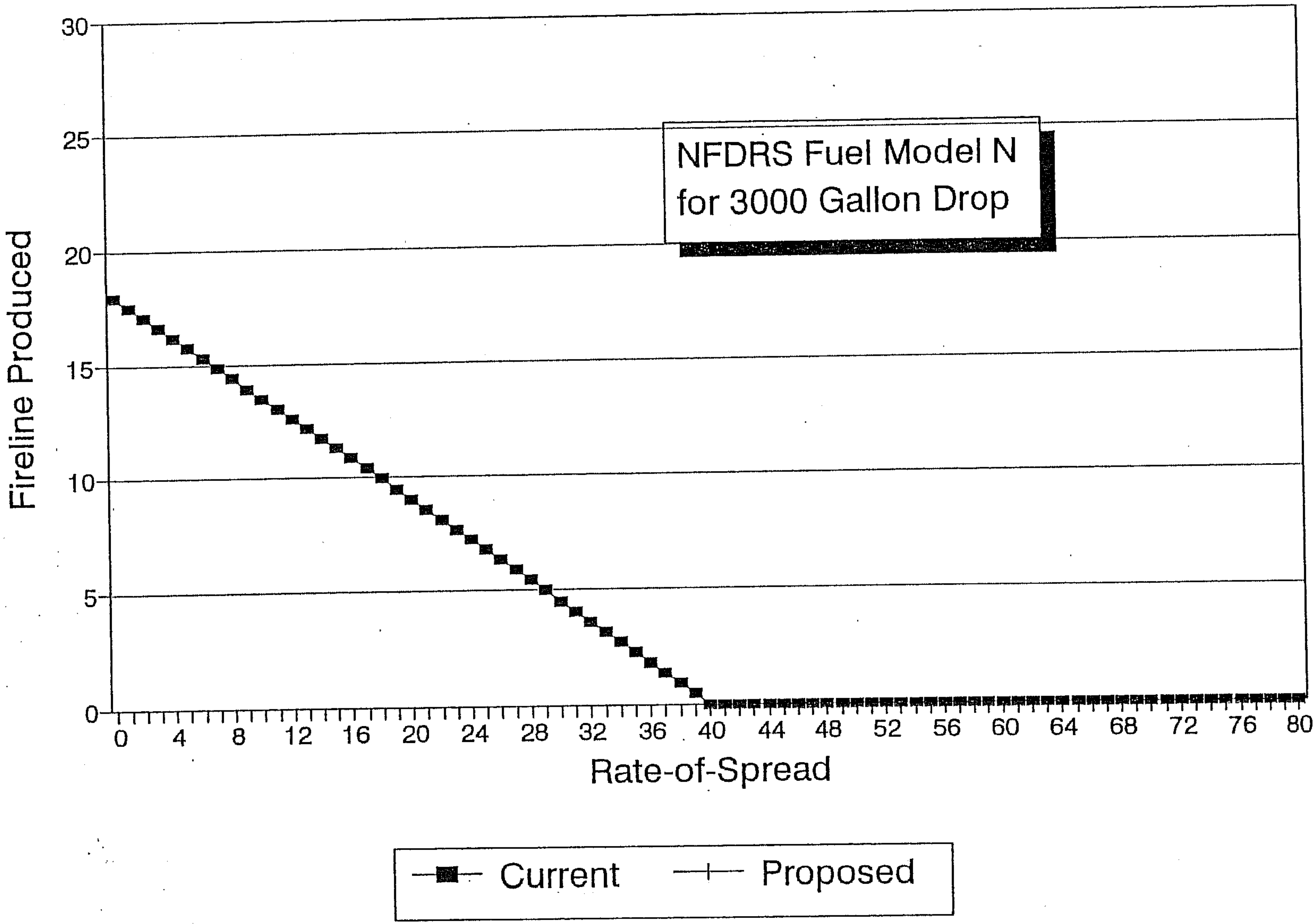

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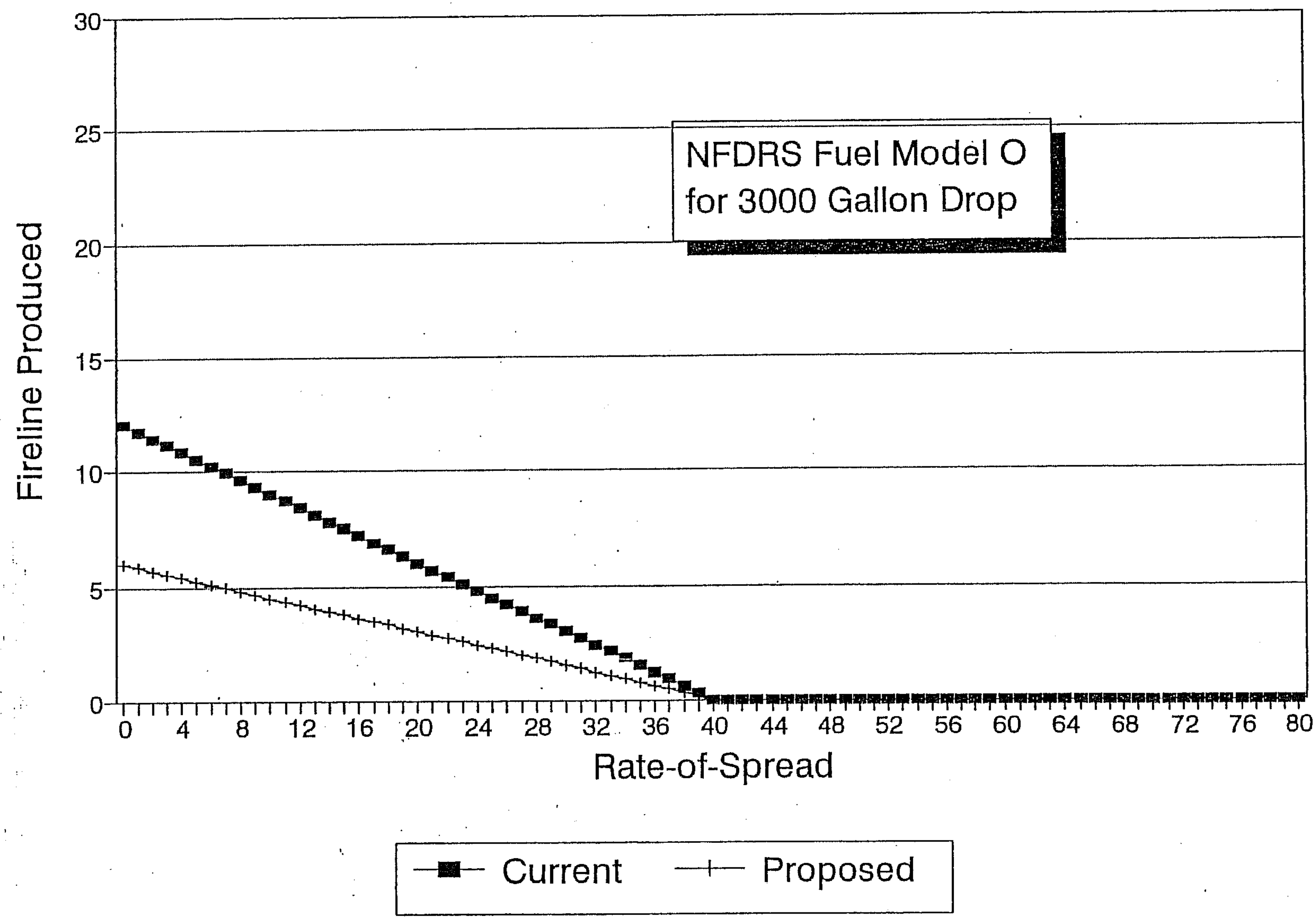

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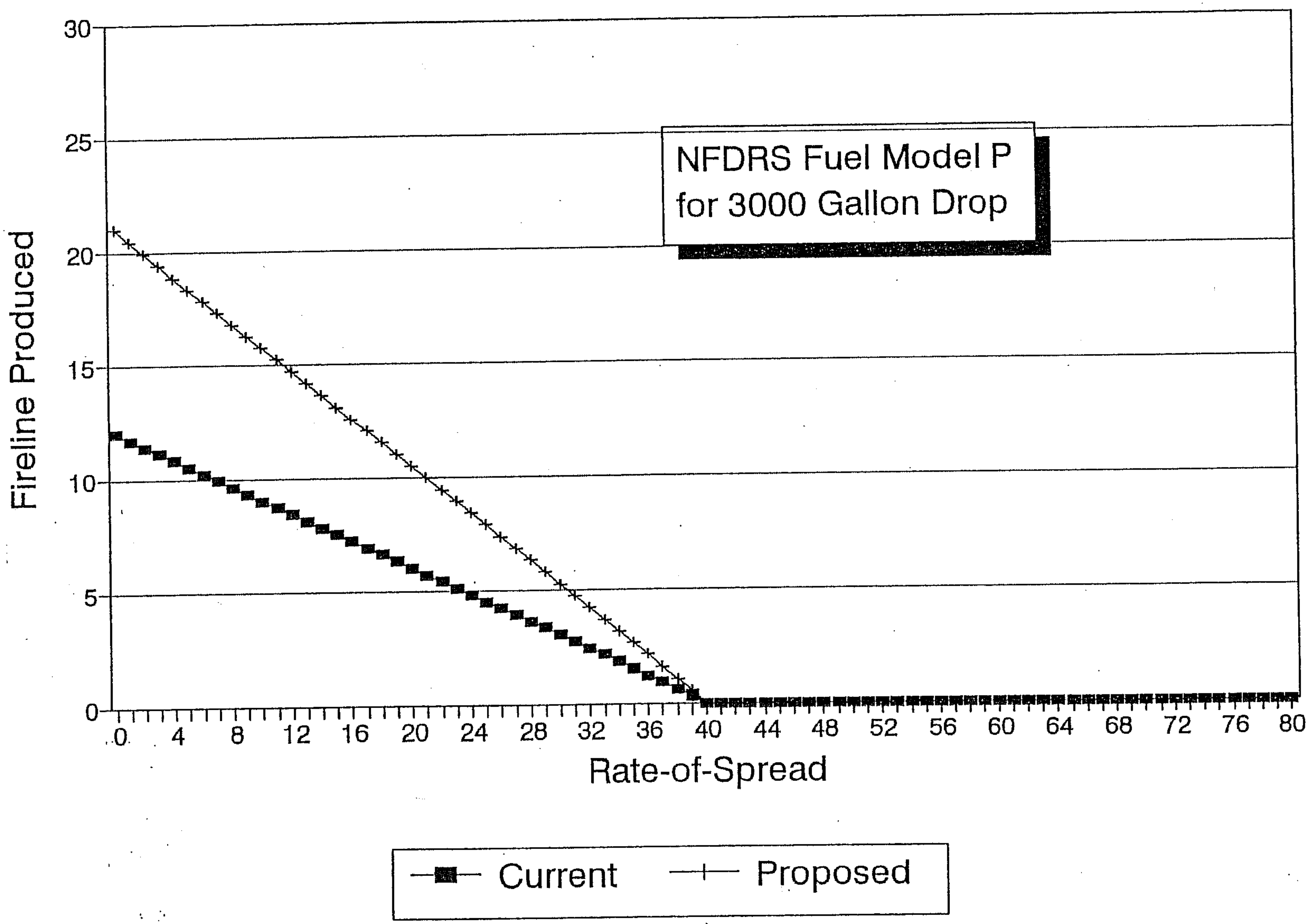
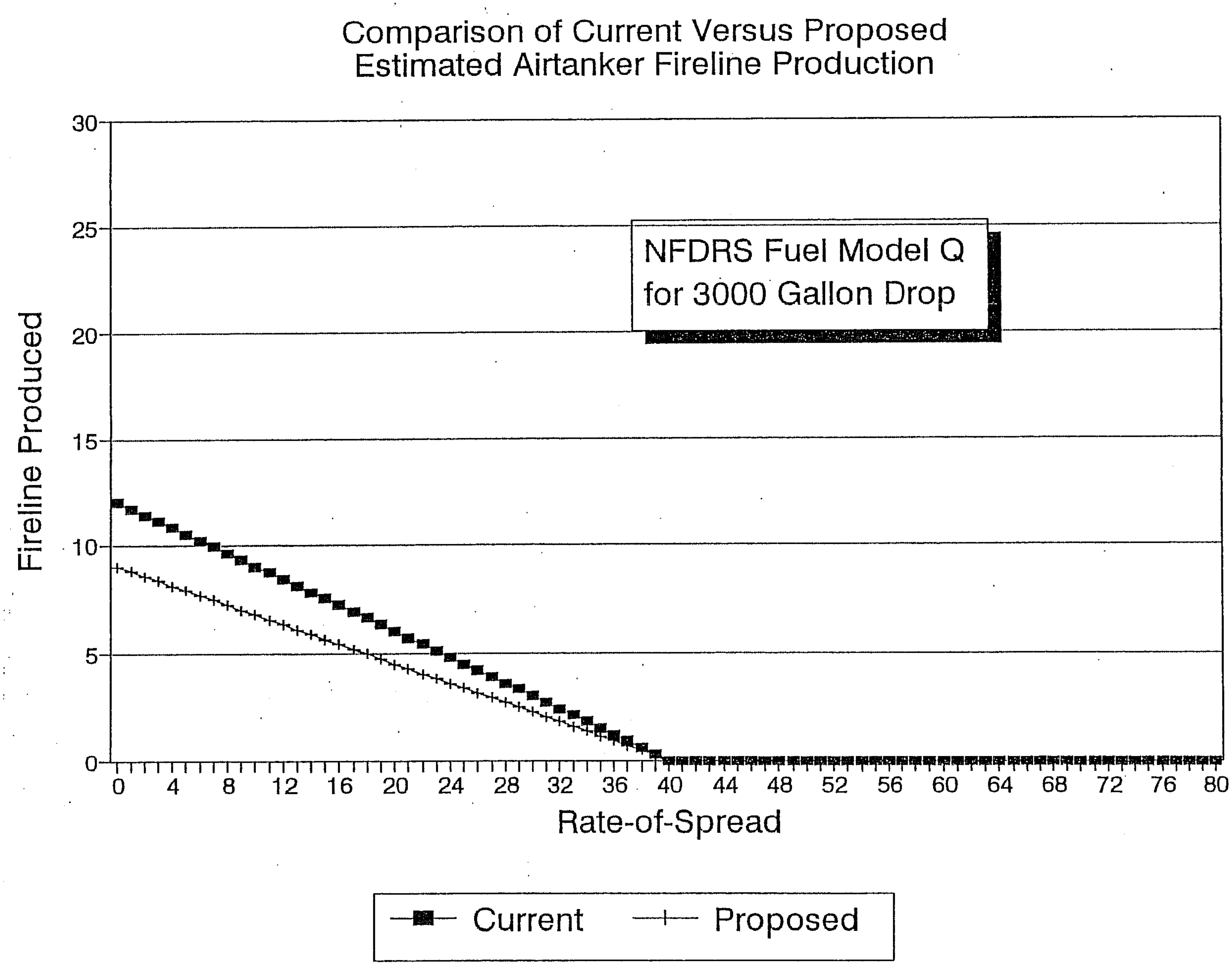
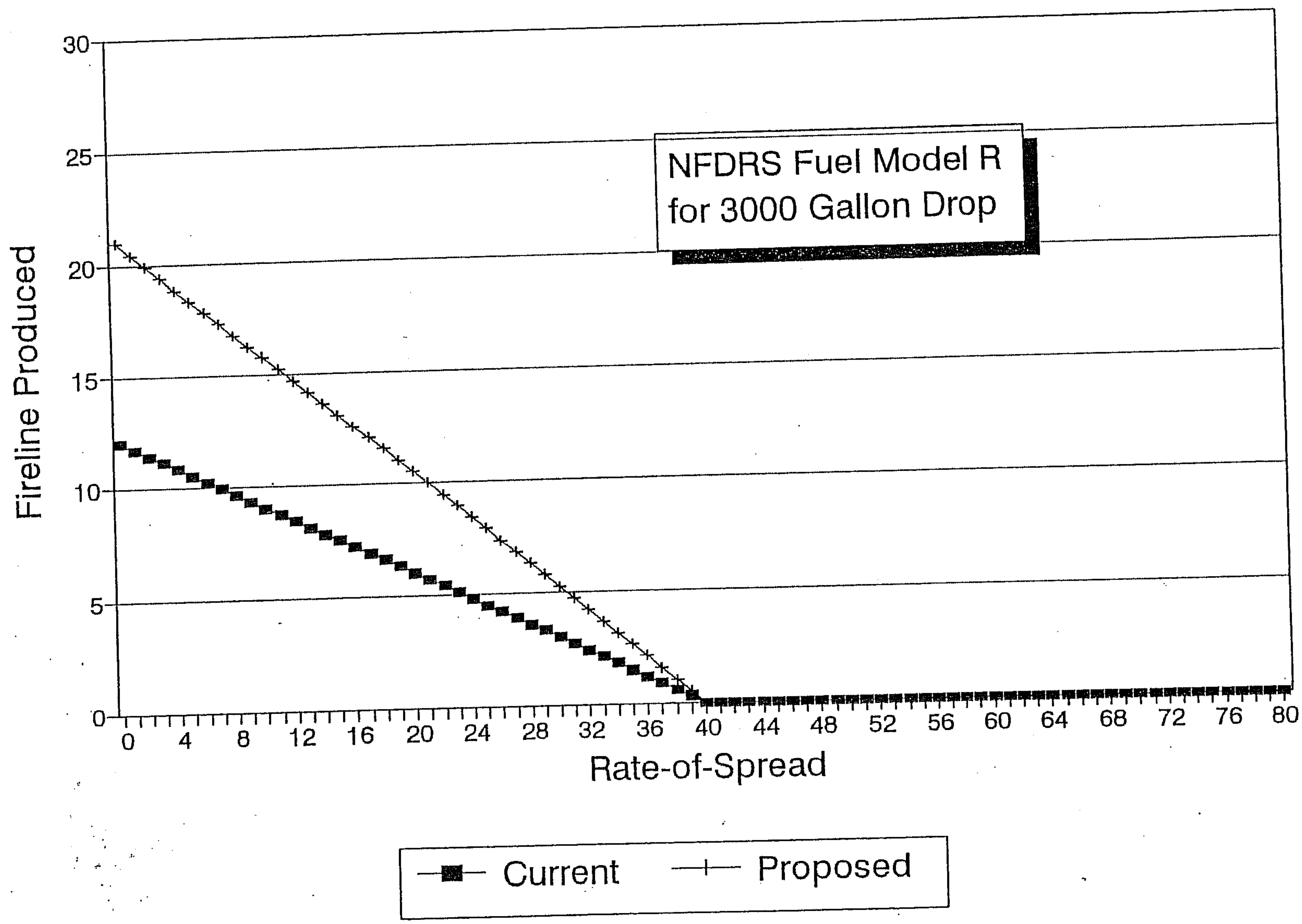



Comparison of Current Versus Proposed
Estimated Airtanker Fireline Production
NFDRS Fuel Model Q
for 3000 Gallon Drop
Fireline Produced
0
5
10
15
20
25
30
Rate-of-Spread
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
80
Current
Proposed

Comparison of Current Versus Proposed
Estimated Airtanker Fireline Production



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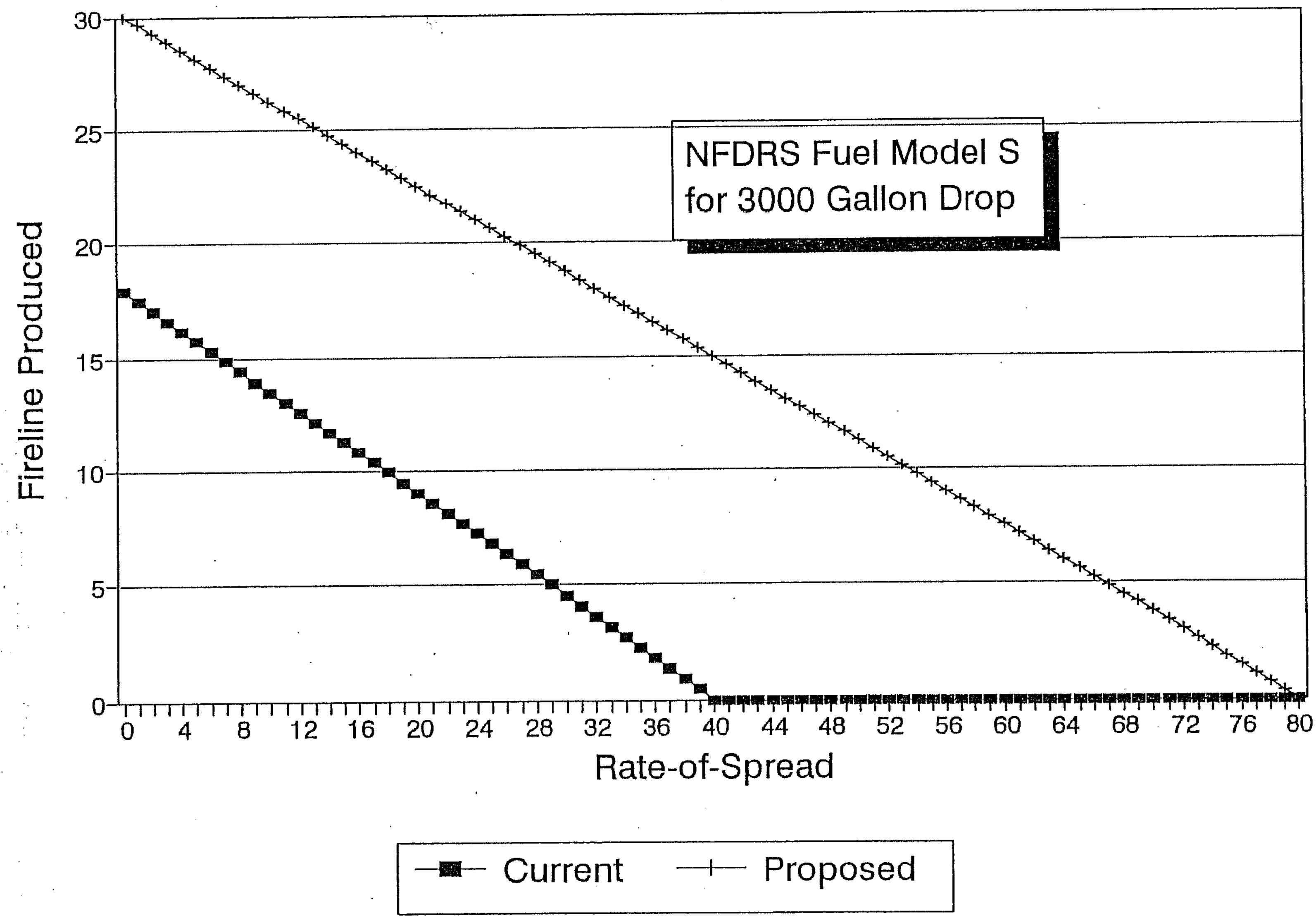

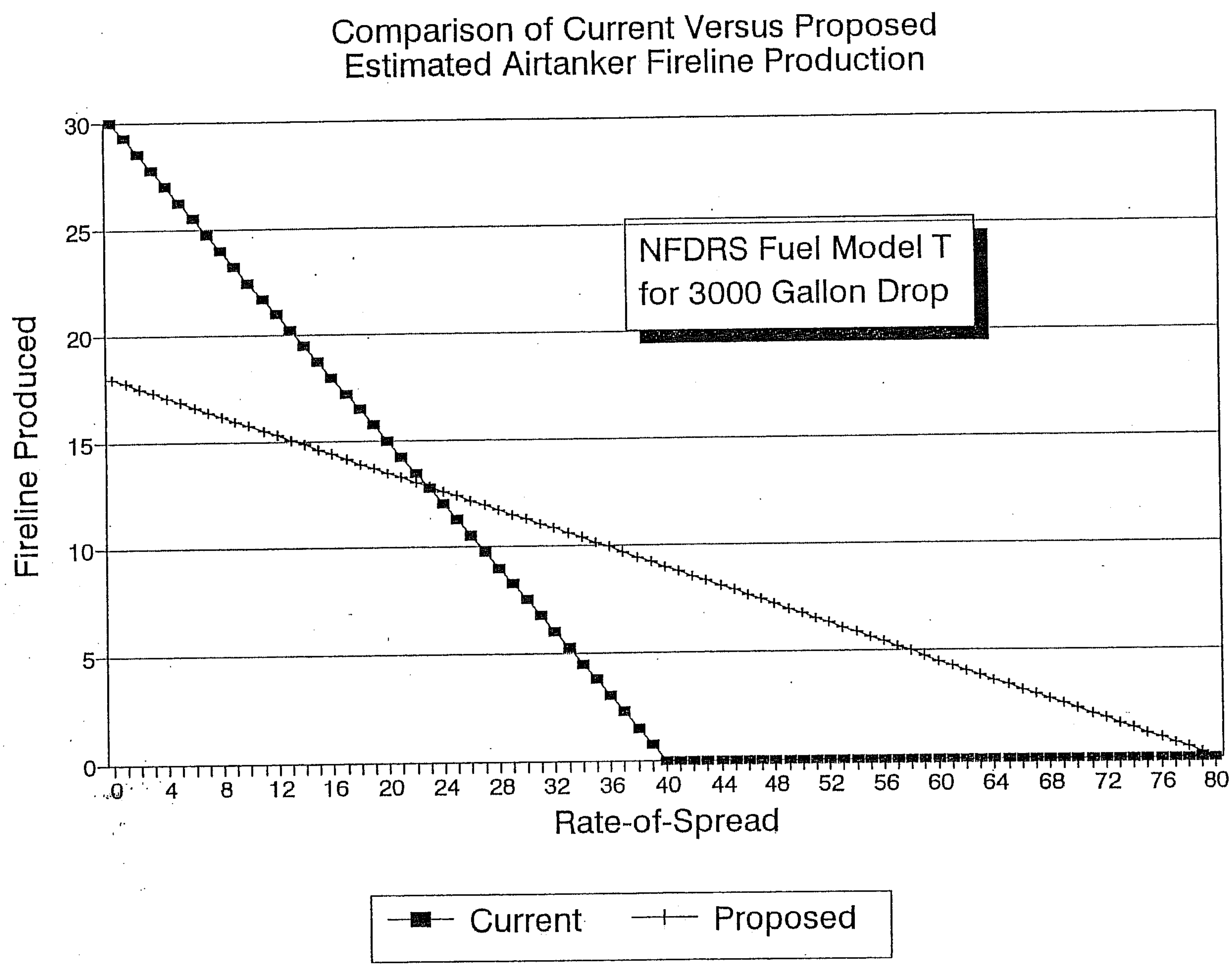
Comparison of Current Versus Proposed
Estimated Airtanker Fireline Production
NFDRS Fuel Model T
for 3000 Gallon Drop
Fireline Produced
0
5
10
15
20
25
30
Rate-of-Spread
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72 76 80
Current
Proposed

Comparison of Current Versus Proposed Estimated Airtanker Fireline Production