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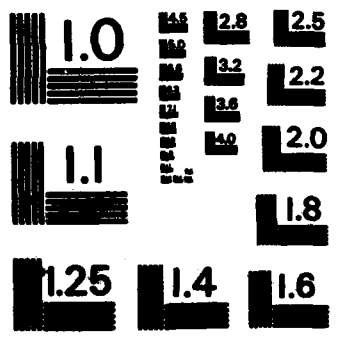
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A propelling charge being designed for the 155mm howitzer will use a combustible cartridge case having a chemical composition similar to that of the 152mm case now being produced by a pulp molding process. The 155mm propellant charge features, however, significant differences in terms of chemical composition, propellant weight and service conditions. This necessitates the upgrading of the 152mm case composition as regards physical strength properties, chemical resistance including nitroglycerin migration, etc., with emphasis on the resin binder. Exploratory experimental investigations were carried		

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out to evaluate different binder resins to optimize the 155mm combustible case composition using preferred binder resins. Based on physical strength measurements two binder resins namely, National Starch & Chemical Resin 78-3730 and Dow Latex 241 (both supplied in latex form) were selected to produce optimized 155mm case compositions and samples of said compositions forwarded to ARRADCOM for further evaluation. The favored case compositions utilize a partially cross-linked binder composition which employs Cymel 300 and ammonium chloride cross-linking additives.

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**AN R&D EXPLORATORY INVESTIGATION OF RESIN  
BINDERS FOR THE COMBUSTIBLE CARTRIDGE CASE  
FOR THE 155MM SELF PROPELLED (SP) HOWITZER  
(XMI98/M109A1) AMMUNITION**

*Walter Brenner and Mujahid Iqbal*

NYU/DAS 80-19

FINAL REPORT - OCTOBER 1980

ARRADCOM



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**NEW YORK UNIVERSITY**  
**FACULTY OF ARTS AND SCIENCE**  
**DEPARTMENT OF APPLIED SCIENCE**

AN R&D EXPLORATORY INVESTIGATION OF RESIN BINDERS FOR THE COMBUSTIBLE  
CARTRIDGE CASE FOR THE 155 MM SELF PROPELLED (SP) HOWIZER  
(XM198/M109A) AMMUNITION

I. INTRODUCTION

One of the propelling charges being designed for the 155 mm SP howitzer will utilize a combustible cartridge case. It is expected that this case will have a composition similar to that of the 152 mm cartridge case and will be manufactured by the same pulp molding process. The 155 mm propellant charge features however, significant differences in terms of chemical composition, propellant weight and service requirements. This will necessitate the employment of a binder resin capable of upgrading the case composition as regards the physical strength properties, chemical resistance especially with respect to introglycerin migration, etc. It is the objective of this research to develop such a case composition, with emphasis on the resin binder, for the 155 mm self-propelled (SP) howitzer XM198/M109A1 ammunition.

II. BACKGROUND

The 152 mm combustible cartridge cases are manufactured from a nitrocellulose based composition by a pulp molding process. The different design and service characteristics that are required for the 155 mm system indicate that the 152 mm combustible cartridge cases' chemical composition be modified particularly with regard to the resin binder. It is expected, however, that the 155 mm combustible cartridge cases will have a general chemical composition similar to that of the 152 mm cases and be manufactured by the same pulp molding process.

The chemical composition of the 152 mm combustible cartridge cases is as follows, said composition understood to be performing satisfactorily in the 152 mm weapon:

Nitrocellulose (12.6% N)	55%	
Kraft fiber		9%
Acrylic fibrillated fiber		25%
Polymeric binder and additive		10%
Diphenylamine		1%

The polymeric binder is a modified polyvinyl acetate resin. The additives are "Acrysol" G-110 and "Lufax" 295.

As noted there are a number of important differences between the 155 mm and the 152 mm weapon systems. The 155 mm propellant charge is several times heavier than the 152 mm propellant charge. The 155 mm propellant is M30A1 which is a triple-base composition. The 152 mm propellant is a double-base composition. The migration of the nitroglycerin into the cartridge case is greater with a triple-base than a double-base propellant. In addition, the 155 mm propellant is expected to be a zoned charge. In view of the larger propellant charge and the likelihood of greater nitroglycerin migration, it will be necessary to employ a binder resin for the 155 mm case that will have better physical strength properties and enhanced resistance to nitroglycerin migration than can be achieved with the presently used polyvinylacetate resin binder. Accordingly this experimental study is primarily concerned with the selection of various resin binders and the preparation of physical test (i.e. tensile) specimens using such different binders chosen with the above noted criteria in mind.

The composition of the 152 mm combustible case as outlined above will be used as a guide in formulating the experimental composition for the 155 mm combustible cartridge cases. The major variable will be the resin binder for meeting 155 mm case needs. All experimental compositions will be fabricated into physical test specimens by the so called "beater addition" method of pulp

molding. After suitable experimental evaluations, in a cooperative effort with the ARRADCOM Project Officer, two binder resins will be selected for the 155 mm combustible case composition. These binder resins will then be employed to fabricate additional test specimens for further testing and evaluation at ARRADCOM.

### III. REQUIREMENTS

Binder resins used for formulating chemical compositions for the 155 mm combustible cartridge case shall be chosen from those known to be resistant to nitro-glycerin absorption and having high physical strength properties as well as their suitability for use with the "beater addition" method of pulp molding. Additional obviously desirable characteristics of candidate binder resins are understood to include long term retention of their pertinent physical strength properties and chemical resistance upon prolonged exposures to anticipated storage and service conditions, ready availability and moderate cost. Initial screening of the binder resins will be carried out by New York University. Selection of preferred systems will be made jointly between the Project Officer and New York University project personnel.

Candidate compositions for the 155 mm combustible cartridge case will then be formulated with various resin binders and fabricated into combustible cartridge case test specimens using the "beater addition" method of pulp molding. The combustible case test specimens for physical strength testing will be in the form of coupons at least six (6) inches long, one (1) inch wide and 0.125 inches thick (nominal). The density of the pulp molded and dried compositions shall be between 0.85 - 0.90 gms/cc.

New York University will determine tensile strengths and percent elongations of the experimental compositions containing the various resin binders on the pulp molded tensile strength test specimens. The tensile strength shall be 2500 psi minimum for an average of six (6) specimens measured at ambient temperatures. The tensile strengths and elongations of the test specimens will also be ascertained after a prolonged storage period at ambient temperatures. Impact strength measurements will be carried out when deemed desirable in consultation with the Project Officer. Resistance to nitroglycerin migration and absorption will be determined by known test methods both at ambient temperatures and over the range of anticipated storage and use conditions as deemed desirable by the Project Officer. Resistance to both liquid water and water vapor as well as other chemicals likely to affect the performance of the 155 mm combustible cartridge cases will likewise be investigated, if necessary, in consultation with the Project Officer.

The "beater addition" method of pulp molding which will be used to fabricate the combustible cartridge case test specimens, will be based on the process technology developed for the production of the 152 mm cases. Standard pulp molding equipment will be employed. The experimental work which will be carried out, will emphasize the application of this process technology so as to produce high quality pulp moldings with the various resin binders of interest. Appropriate modifications of significant pulp molding process variables will be made as required so as to obtain optimal quality test specimens for specific resin binders. In all cases the maximum amount of the polymeric resin binder and any other additions employed in the pulp molded test specimens will be limited to 10% of their total weight.

The nitrocellulose (12.6% N) and the fibrillated acrylic fiber required for these experimental investigations by New York University will be furnished by the Government as needed. New York University will safely store the nitrocellulose and all other materials used for this investigation. The University will also obtain a DOT Hazard Classification for any new materials that are developed under this contract. In view of the fact that the case composition will contain nitrocellulose (12.6% N), the temperatures used during pulp molding and drying of the specimens shall not exceed 260 F (127 C). If the nature of the resin binders should be such that a higher temperature is required, then the Government shall perform the necessary sensitivity tests before such higher temperatures are employed in the experimental studies.

#### IV. EXPERIMENTAL

The basic approach encompassed the selection of candidate resin binders followed by the formulation of experimental chemical compositions for the manufacture of 155 mm combustible cartridge cases and the preparation of hand sheets by the "beater addition" method of pulp molding with said case compositions. The hand sheets were made on a 8"x8" Williams Sheet Mold (Williams Apparatus Co., Watertown, N.Y.) using a 8"x8" 64 mesh bronze screen standard laboratory paper making unit and measured 8"x8". The hand sheets were dried, pressed, etc., prior to cutting into test specimens of the size required for the tensile strength tests. During the processing of the hand sheets, the maximum temperatures were kept to a maximum of 175 F (79 C) at all times. The drying of the hand sheets was accomplished by heating them in a Fisher Model 349 Convection Oven (Fisher Scientific Company, Springfield, N.J.). A 8"x8" platen size Carver Laboratory Press (Carver Inc., Menomonee Falls, Vt.) was employed for pressing the hand sheets.

As indicated above, a technical survey was first carried out to identify candidate resin binders for the formulation of improved chemical compositions for manufacture of 155 mm combustible cartridge cases by the "beater addition" method of pulp molding. Some of the considerations which were employed to identify promising resin binders for this application included resistance to nitroglycerin absorption; physical strength properties; processability with emphasis on suitability for use with the "beater addition" method of pulp molding; retention of pertinent physical strength and chemical resistance properties upon prolonged exposures to anticipated storage and service conditions; availability and cost. Additives for use in conjunction with resin binders in "beater addition" processes pulp molding processes were likewise investigated. All U.S. manufacturers of potentially applicable resin binders were contacted during this survey.

The resin binders and additives with potentially attractive property/performance profiles identified as a result of this survey were considered to include styrene and high styrene content types of polymers and copolymers, selected urethanes and some modified acrylic polymers. A partial list of typical candidate polymeric binders is shown in Table #1. Suitable beater additives included such products as Acrysol G110, Lufax 295 and Primafloc C-3 (all from the Rohm and Haas Co., Philadelphia, Pa.) and the Natron polymeric materials from National Starch and Chemical Co. (Bridgewater, N.J.). Appropriately sized samples of various candidate resin binders and additives were obtained for carrying out the experimental work. The various resin binder samples were all obtained in the latex form.

The preliminary results obtained from the evaluation of the physical strength properties of a few handsheets made with typical binder resins suggested the partial cross-linking of resin binders in order to obtain a higher level of physical strengths and also optimize their chemical resistance characteristics. This could be achieved with those resin binders which exhibit suitable chemical reactivity, i.e., have reactive functional groups in their molecular structure. A cross-linking system based on Cymel 300 (hexa methoxymethylamine, American Cyanamid Company, Wayne, N.J.) and an accelerator, ammonium chloride, was developed and proved suitable for effecting controlled cross-linking of selected resin binders with appropriate functional reactive groups. The Cymel 300 and the ammonium chloride were added to the "beater addition" type pulp molding formulation.

Experimental result of these investigations are summarized in Table 2 which shows the effect of different resin binders on the physical strength properties of pulp molded combustible cartridge case compositions in terms of their tensile strength and tensile elongation. These data are compared with the physical strength properties of the presently used 152 mm combustible cartridge case material, also measured in terms of tensile strength and tensile elongation. This material was cut from a production lot XM205E2 combustible 152 mm cartridge case. All the test data shown are comparable since as indicated above, the maximum resin binder content was limited to 10% of the weight of the case material all other additives included.

A limited amount of tests were run to ascertain the effect of storage time (no temperature or humidity control) at ambient temperatures for three typical experimental chemical compositions only differing by the resin binder used.

data are summarized in Table 3. They show clearly no significant effect storage times up to 6 months at ambient temperature storage conditions for three different binder compositions tested. Additional storage tests indicated in order to obtain analogous data for the other experimental positions which were not tested. Also more testing of this type should be carried out for longer time periods and/or a range of storage conditions. Based upon the results obtained thus far and the experience gained with 152 mm combustible cases over a number of years, it is believed that the storage capacity of these candidate combustible cartridge case compositions will fully meet anticipated storage requirements.

Laboratory tests were also carried out to determine the effect of water immersion at ambient temperatures for a few experimental chemical compositions again varying only by the resin binder used. The results of these tests are shown in Table 4. They indicate that coating of the case material with a urethane resin or other water repellent material should be considered in order to minimize the water pick-up's obtained upon water immersion. The use of water repellent in ordnance items is well established and the small quantity required should not in any way affect the performance characteristics of the 155 mm combustible cartridge cases. As a matter of fact such a treatment must be deemed as highly desirable in order to enhance case combustibility in a humid or wet environment where water pick-up can be expected.

A limited amount of thermal cycling was performed. Two different experimental combustible cartridge case compositions were subjected to a simple thermal cycling test. This test consisted of heating tensile strength test specimens to 120 F (C) in a Fisher Model 349 Convection Oven, keeping them at that temperature

for one hour; cooling to 26 F (-3 C); keeping them at 26 F (-3 C) for one hour, heating again to 150 F (66 C) and repeating this thermal regime for a total of 4 cycles. The tensile strengths and elongations of the test samples were shown to be not affected. Additional testing using more severe thermal cycling including humidity exposures, is recommended in order to develop this information to the extent needed based on anticipated case environmental service conditions.

V. SUMMARY AND CONCLUSIONS

Exploratory experimental investigations were carried out in order to upgrade the performance characteristics of the 152 mm combustible cartridge case material so as to make it suitable for the more stringent requirements of the 155 mm weapon system. The basic approach taken encompassed the selection and use of a candidate resin binder in the case composition whose employment would enhance both case physical strengths and also chemical resistance particularly as regards nitroglycerin migration and absorption. Tensile strength tests, etc. of test coupons prepared by the "beater addition" method of pulp molding resulted in the selection of two commercially available resin binders which exhibited remarkably superior strength properties -- about twice the strength exhibited by the 152 mm case material -- and also significantly improved chemical resistance. Additional test specimens were then fabricated using these two preferred binders and forwarded to ARRADCOM for further testing and evaluation.

The two preferred binder resins were National Starch and Chemical Company's Resin 78-3730 and Dow Chemical Company's Latex 241 (both supplied in latex form). National Starch and Chemical Company's Resin 38-3740 is an anionic styrene/

acrylic copolymer latex containing about 60% styrene. Dow Latex 241 is an anionic styrene/butadiene copolymer latex containing in the order of 40% styrene. The best properties were obtained when the recipe for the cartridge case composition was modified so as to include quite minor amounts of selected additives which made possible partial cross linking of the resin during fabrication of the case material. These additives were Cymel 300 obtained from the American Cyanamid Company, and ammonium chloride. Tensile strengths and elongation properties were far superior for case compositions with these partially cross linked binder resins compared to those exhibited by the XM205E2-152 mm case composition. Specifically, tensile strengths were in the order of 5500 psi with elongations of 10-11% vs tensile strengths of only 2800 psi and elongations above 20%. Chemical resistance characteristics were likewise improved. These data can be interpreted in terms of substantially improved strength and serviceability for the 155 mm combustible cartridge cases.

It should be emphasized that the results of this exploratory experimental investigation while obviously most promising, should not be viewed as the optimal property profile which is attainable. Additional R&D on these and other resin binders will have to be carried out in order to optimize both case formulations and fabricating techniques. As a matter of fact there are a number of resin binder systems which appear feasible such as nitrocellulose/urethanes and nitrocellulose/acrylics, whose use is forecast as likely not only to improve both physical strengths and chemical resistance, but also enhance combustibility. It is therefore recommended that a suitably designed experimental program directed towards this goal be initiated.

TABLE I. TYPICAL CANDIDATE BINDER RESINS

BINDER RESIN DESIGNATION	% SOLIDS	TYPE	MANUFACTURER
Dow Latex 288	50	100% styrene	Dow Chemical Co., USA
Exp'tl Latex XD33J6.16	46	95/5 styrene/butadiene copolymer, anionic	" " " "
Dow Latex 241	50	40/60 styrene/butadiene copolymer; anionic	" " " "
Dow Exp't Latex XD30193.00	43	75/25 styrene/butadiene copolymer; anionic	" " " "
Dow Latex 233	50	60/40 styrene/butadiene copolymer; anionic	" " " "
Rucothane Latex 2010L	65	polyurethane, nonionic	Hooker Chemical Co.
Rucothane Latex 2030L	62	polyurethane, nonionic copolymer; anionic	" " " "
Rucothane Latex 2050L	60	polyurethane, nonionic	" " " "
Rucothane Latex 2060L	57	polyurethane, nonionic	" " " "
Exp'l Emulsion E1000	46	Modified self cross linking anionic acrylic	Rohm & Haas Co.
Rhoplex P50-1	43	Modified self cross linking anionic acrylic	" " " "
Rhoplex TR 621	55	Modified self cross linking anionic acrylic	" " " "
Resyn 72-3346	46	anionic acrylic type copolymer	National Starch & Chem., Co.
Resyn 78-3730	50	anionic acrylic/styrene copolymer, 60% styrene	" " " "
Resyn 78-3936	50	hydroxyl functional styrene/acrylic	" " " "
Resyn 3383-31	47	self cross linking styrene/acrylic copolymer	" " " "
Resyn 3623-123	51	self cross linking vinyl acetate latex	" " " "
Goodrite 2507	40	anionic styrene/butadiene copolymer; 40% styrene	B.F. Goodrich Chem., Co.
Goodrite 2507 x 5	40	anionic styrene/butadiene copolymer; 30% styrene	" " " "
Hycar 1800 x 73	40	styrene/acrylate copolymer; 45% styrene	" " " "
Hycar 1562 x 103	40	styrene/butadiene copolymer	" " " "
Airflex A-400	48	vinyl acetate polymer	Air Products & Chem., Co.
Vinac XX 230	48	modified vinyl acetate type polymer	" " " "
Ucar 153	48	modified vinyl acetate type polymer	Union Carbide Corporation
GAF 4465	46	polyvinylpyrrolidene polymer	GAF
Johnson Versacryl 763	35	modified acrylic type polymer	Johnson
Hypo1 WB4000	65	modified urethane polymer	W.R. Grace & Company

TABLE II

SAMPLE		Tensile Strength lbs/sq. in.	Elongation %	Density
1.	152 MM case material from XM205E2 case	2813	25.7	.906
2.	Resin 7803720; National Starch styrene Acrylate 60% styrene	3900	19.5	.911
3.	Latex 288; Dow Chemical Styrene Butadiene 100% styrene	2784	24.2	.897
4.	Latex 241; Dow Chemical styrene butadiene 39.2% styrene	2871	33.0	.860
5.	Dow Exp'l Latex XD 339616; Dow Chemical styrene butadiene 95% styrene	2945	30.3	.878
6.	Latex 233; Dow Chemical styrene butadiene 40% styrene	2744	41.0	.823
7.	Dow Expt'l Latex XD30193.00; Dow Chemical styrene butadiene 75% styrene	2914	27.5	.873
8.	Goodrite 2507; B.F. Goodrich styrene butadiene 39.7% styrene	3327	29.3	.881
9.	Goodrite 2507 x 5; B.F. Goodrich styrene butadiene 30% styrene	3075	36	.869
10.	Hycar 1800 x 73; B.F. Goodrich styrene acrylate 45% styrene	3219	36.5	.879
11.	Airflex A-400	3800	18.06	.902
12.	Vinac XX230	2710	35	.850
13.	Hycar 1562X 103 B.F. Goodrich	3300	20.8	.891
14.	Ucar Latex 153 Union Carbide	2515	42	.799
15.	Rucothane 2060L Hooker	3665	19.6	.896
16.	Rucothane 2050 L Hooker	3547	20.1	.894
17.	Rucothane 2030L Hooker	3440	22.6	.901
18.	Rucothane 1010L Hooker	3510	21.4	.903
19.	GAF 4465 GAF	2690	36.5	.788
20.	Johnson Versacryl 763	3820	19.01	.911
21.	Rhoplex P50-1; Rohm & Haas self cross linking anionic acrylic	2250	43.7	.890
22.	Rhoplex TR621; Rohm & Haas	2194	36.9	0.910
23.	Expt'l Emulsion E1000; Rohm & Haas	2328	38.1	.893
24.	Hypol WB4000; W.R. Grace & Co. modified polyurethane latex	2086	37.2	.906

TABLE II (Cont'd)

SAMPLE			Tensile Strength lbs/sq. in.	Elongation %	Density
Resin 78-3730 National starch cross linked w/ Cymel 300*					
	i	50%	4600	17.1	.917
	ii	40%	4480	18.4	.903
	iii	25%	4120	19.2	.891
	iv	10%	4100	19.5	.887
	v	5%	4000	20.02	.893
Resin 78-2730 National Starch cross linked with Cymel 300 and ammoniumchloride (NH <sub>4</sub> Cl) as accelerator					
		<u>% CYMEL 300*</u>			
		<u>% NH<sub>4</sub>Cl*</u>			
	i	5%	4680	13%	.909
	ii	10%	5320	11.8%	.918
	iii	20%	5300	11.6	.918
	iv	30%	5510	10.7	.920
	v	40%	5600	9.6	.925
	vi	50%	5680	9.9	.920
Dow Latex 241 crosslinked with Cymel 300 and ammoniumchloride accelerator					
		<u>% CYMEL 300*</u>			
		<u>%NH<sub>4</sub>Cl*</u>			
	i	5%	4960	12.7	.906
	ii	10%	5518	12.7	.920
	iii	20%	5630	12.2	0.919
	iv	30%	5624	11.9	0.906
	v	40%	5607	12.4	0.923
	vi	50%	5653	12.2	0.936
National Starch Resin 78-3936 cross linked w/ Cymel 300 and ammonium chloride accelerator					
	i	20%*	5490	10.2	0.911
National Starch Resin 3383-31 cross linked w/ Cymel 300 and ammoniumchloride					
	i	20%*	5335	11.6	0.906
National Starch Resin 3623-123 cross linked w/ Cymel 300 and ammonium chloride accelerator					
	i	20%*	5510	10	0.921

\*based on dry binder resin weight

TABLE III. EFFECT OF PROLONGED AMBIENT TEMPERATURE STORAGE ON THE PHYSICAL STRENGTH PROPERTIES OF EXPERIMENTAL COMBUSTIBLE CARTRIDGE CASE COMPOSITIONS FOR THE 155 MM CASE

EXPT'L CASE COMPOSITION	INITIAL		CONDITION A <sup>1)</sup>		CONDITION B <sup>2)</sup>	
	Tensile Strength PSI	Elongation %	Tensile Strength PSI	Elongation %	Tensile Strength PSI	Elongation %
XN205 E2 case sample	2813		2786		2845	
Resin 78-3730	3900	19.5	3940	23.4	3874	21.3
Latex 241	2871	33.0	2864	31.8	2942	35.6
Hycar 1800 x 73	3219	36.5	3098	37.2	3126	38.0
Rucothane 2030L	3440	22.5	3486	23.5	3339	24.1

1) 3 months storage at ambient temperatures; no temperature or humidity control

2) 6 months storage at ambient temperatures; no temperature or humidity control

TABLE IV. EFFECT OF AMBIENT TEMPERATURE WATER IMMERSION ON THE WEIGHT OF EXPERIMENTAL COMBUSTIBLE CARTRIDGE CASE COMPOSITIONS FOR THE 155 MM CASE

EXP'L CASE COMPOSITION	WATER IMMERSION, PERIOD DAYS, % PICK UP				
	1	3	6	10	
XM205 E2 case sample	2.9	8.7	12.0	21.3	
	2.7	6.7	11.6	-	
Resin 78-3730	3.49	9.9	20.6	22.5	
Latex 241	2.5	11.7	29.3	26.8	
Hycar 1800 x 73	2.1	7.2	11.1	21.6	
Rhom & Haas - Rhoplex TR520	2.9	8.2	12.9	-	