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METAL CLAD ARAMID FIBERS FOR AEROSPACE WIRE AND CABLE

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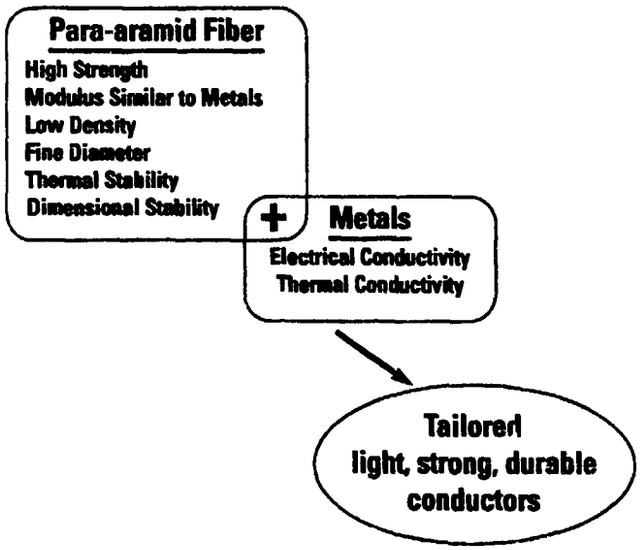
Abstract

High strength, light weight metal clad aramid fibers can provide significant weight savings when used to replace conventional metal wire in aerospace cable. This paper provides an overview of metal clad aramid fiber materials and information on performance and use in braided electrical shielding and signal conductor.

Background

ARACON* combines DuPont para-aramid fiber technology with metal claddings...



* ARACON is a tradename of a product manufactured by the DuPont Company. Trade names or manufacturers' names are used in this report for identification only. This usage does not constitute an official endorsement, either expressed or implied, by the National Aeronautics and Space Administration.

Base P-aramid Fiber Properties

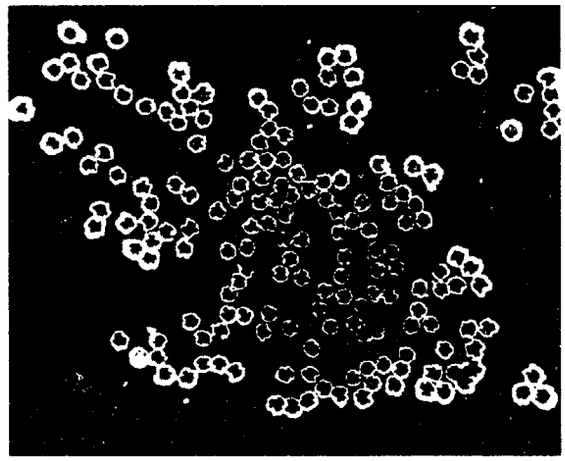
	Nominal
Tensile Strength	425 Ksi
Tensile Modulus	12 - 25 Msi
Elongation	3% - 4%
Specific Gravity	1.4
Filament Diameter	0.6 mil
Decomposition Temperature	500°C

Comparison of Specific Gravities

Material	Specific Gravity
Copper	8.9
Nickel	8.9
Tin	7.3
Silver	10.5
Aluminum	2.7
ARACON	
65% metal	3.1
85% metal	5.0

Product Offering

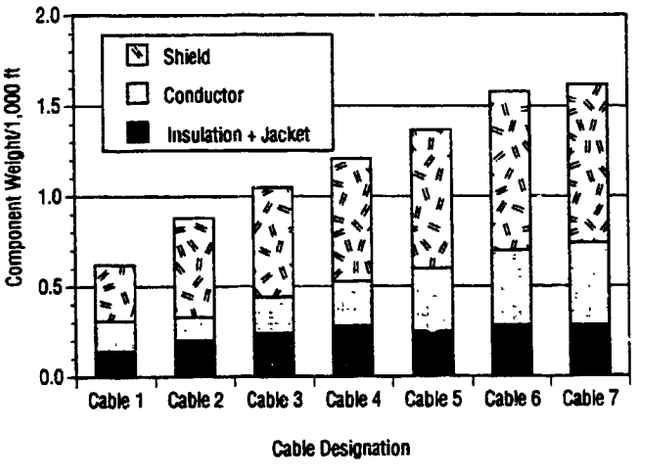
Properties	Base Yarn	vs. Copper
Individual Fiber Diameter	0.6 mil (~ 54 AWG)	—
Fiber Tensile Strength, Ksi	350 min.	35 - 95
Fiber Tensile Modulus, Msi	12 min.	—



Key Benefits of ARACON Over Traditional Copper Conductors Include:

- Weight savings
- Strength and durability
- Flexibility
- Tailored electrical/ mechanical property balance

Weight Savings Potential for Cables
(Variety of Aerospace Cable Types)



Concept

Replace Wire in Shield and/or Conductor with Metal Clad Aramid Fiber

Product Types

ARACON™ Size	No. of Filaments (No. of Conductors)	Apprx. AWG
55	24	38
200	89	32
400	178	30
600	267	28
1125	500	26

Metallic clads available: Nickel
Copper
Tin
Silver

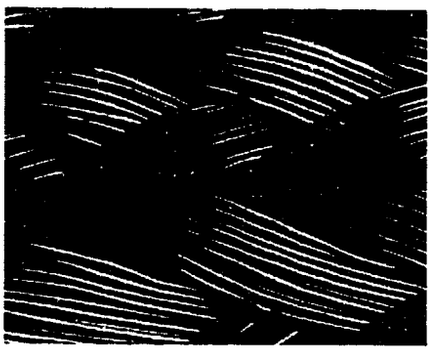
Range of metal cladding possible: 15 wt% to 90 wt%

Major interest to date in 65% to 85% metal content

Most Experience to Date in Braided Shielding

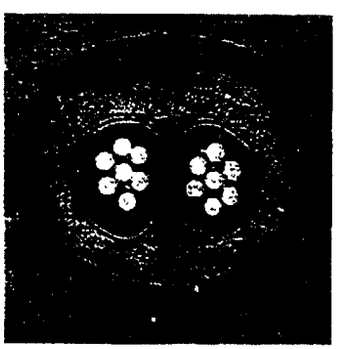
Shielding

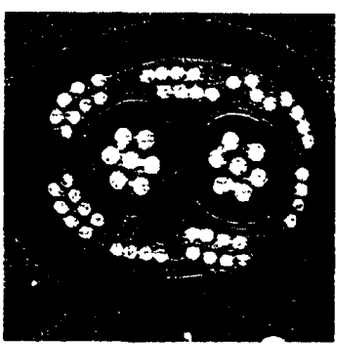
Copper Wire Braid



ARACON Braid

Coverage

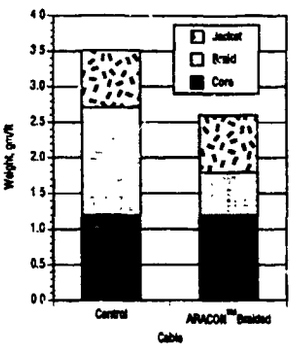




ARACON offers greater coverage in shielding applications without impairing pushback capability.

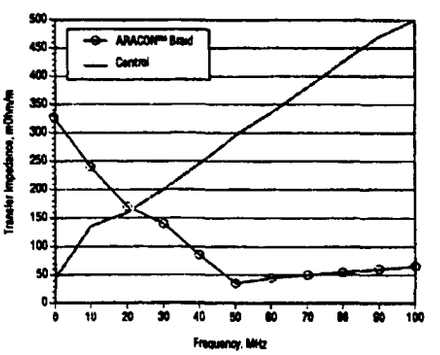
- **Large number of flexible, fine diameter conductors**

Twisted Pair Cable Comparison



Cable Component Weights

Transfer Impedance vs. Frequency



Case Study — Shielding

Coaxial Cable Comparison

At very high (GHz) frequencies, ARACON can improve shielding and reduce weight.

		Shielding Effectiveness, dB	
	% wt/ft	2 - 4 GHZ	16 - 18 GHz
Single Braid			
RG58	100	57	52
RG58 ARACON	77	68	85
Double Braid			
RG223	100	94	107
RG223 ARACON	72	124	110

Braid Resistance Before and After 10K amps Lightning Strike Tests

Cable Number	Shield Description	Cable Dia. (in.)	Initial Resistance (mOhm/m)	Resistance After Six Strikes, Waveform 1* (mOhm/m)	Resistance After Six Additional Strikes, Waveform 5E** (mOhm/m)
1	Control - Wire	0.40	3.80	3.70	3.60
2	Control - Wire	0.68	1.70	1.70	1.50
5	ARACON 70% - 85% Cu/Ni	0.40	12.00	12.50	11.00
6	ARACON 70% - 85% Cu/Ni	0.68	46.50	44.00	42.50
7	ARACON 50% - 69% Cu/Ni/Sn	0.40	80.50	68.00	57.50
8	ARACON 50% - 69% Cu/Ni/Sn	0.68	30.00	30.00	30.50
9	ARACON 70% - 85% Cu/Ni/Sn	0.40	11.50	10.50	10.20
10	ARACON 70% - 85% Cu/Ni/Sn	0.68	14.00	14.50	14.50

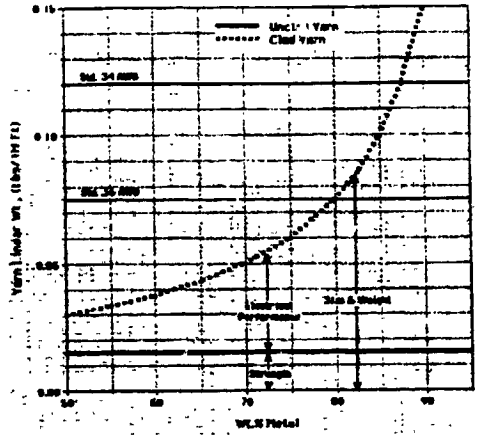
*Commercial aircraft test waveform
**Military aircraft test waveform

Minimal effect of lightning strike, variations depend on metal content and diameter.

Conductor

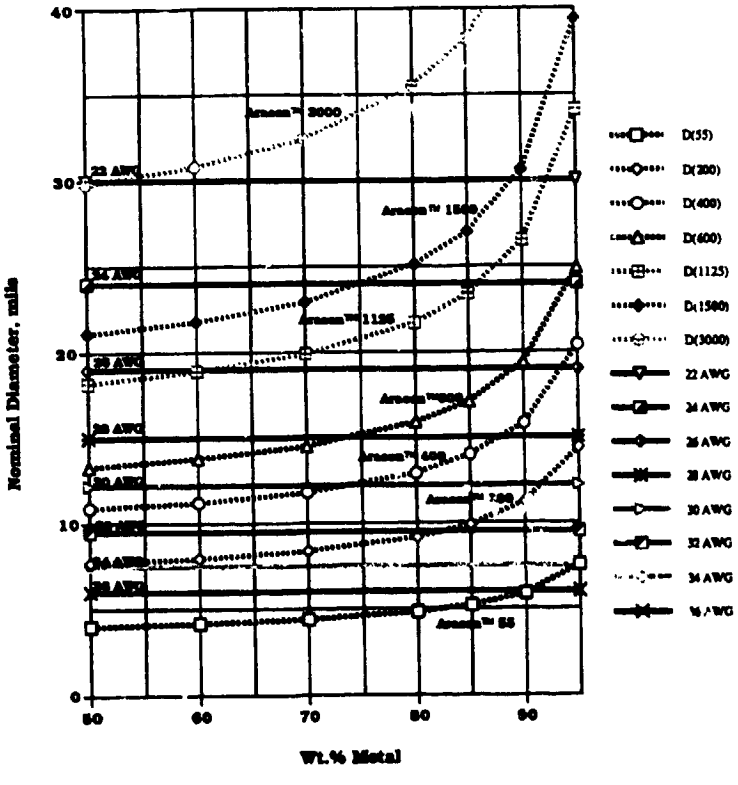
ARACON Linear Weight vs. % Metal

200d Base Product



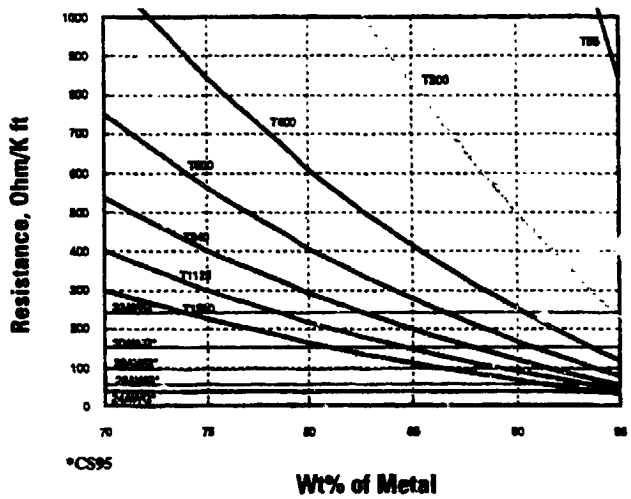
- **ARACON offers an opportunity to provide lightweight conductors with the ability to separately tailor weight, strength and electrical properties.**

Comparison of Diameters
Std. Stranded AWG vs. Aracon



ARACON Resistivity vs. Metal Content

Estimated Values

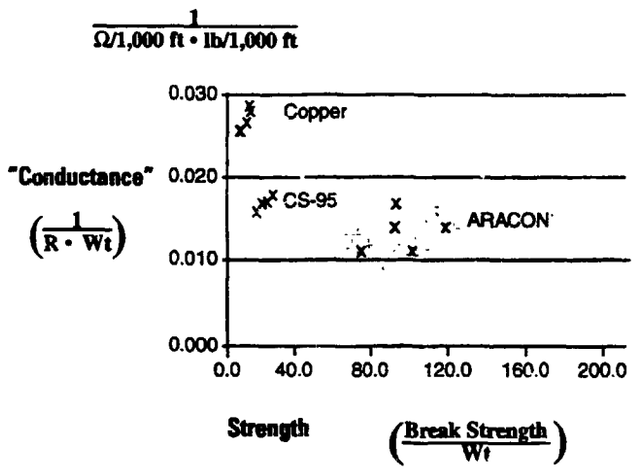


ARACON resistivity can be tailored to meet design requirements.

Preliminary Typical Properties Comparison

AWG	Material	Dia. (mil)	Construction	Type	DC Resistance Max. (Ohms/M)	Wt. Max. (lb/M ft)	Break Strength (lb)
2-	Cu/Ag	23.0-23.7	19/36	Unilay	23.6	1.45	13
	CS-95	23.6-24.8	19/36	Unilay	36.4	1.51	34
	CS-95/Ag	23.6-24.8	19/36	Unilay	35.9	1.52	34
	Cu/Ni	23.0-24.0	19/36	Unilay	25.2	1.51	13
	ARACON	23-25	1500d/70-80	Unilay	170-305	0.37-0.56	55-60
	ARACON	23-25	1125d/84-88	Unilay	110-176	0.52-0.7	40-45
	ARACON	23-25	840d/90-92	Unilay	95-130	0.62-0.78	30-35
26	**Cu/Ag**	**18.4-19.0**	**19/38**	**Unilay**	**37.3**	**0.932**	**9**
	CS-95	**18.8-20.0**	**19/38**	**Unilay**	**57.4**	**0.973**	**21.5**
	CS-95/Ag	**18.8-20.0**	**19/38**	**Unilay**	**56.4**	**0.982**	**21.5**
	Cu/Ni	**18.4-19.2**	**19/38**	**Unilay**	**41**	**0.979**	**9**
	ARACON	**18.5-20**	**1125d/50-70**	**Unilay**	**400-1200**	**0.18-0.28**	**40-45**
	ARACON	**18.5-20**	**840d/80-84**	**Unilay**	**210-380**	**0.31-0.39**	**30-35**
	ARACON	**18.5-20**	**400d/93-95**	**Unilay**	**120-160**	**0.39-0.6**	**16-18**
28	Cu/Ag	14.0-14.9	19/40	Unilay	63.1	0.582	5
	CS-95	14.4-15.6	19/40	Unilay	97	0.594	12.7
	CS-95/Ag	14.4-15.6	19/40	Unilay	94.9	0.599	12.7
	Cu/Ni	14.0-15.4	19/40	Unilay	67.6	0.603	5
	ARACON	14-15.5	400d/85-89	Unilay	190-240	0.2-0.27	16-18
30	Cu/Ag	12.0-13.0	19/42	Con	96.1	0.404	3
	CS-95	11.9-13.0	19/42	Con	152	0.392	8.2
	CS-95/Ag	11.9-13.0	19/42	Con	148	0.397	8.2
	Cu/Ni	11.8-14.0	19/42	Con	109	0.469	3
	ARACON	12-14	400d/72-85	Unilay	400-1000	0.11-0.2	16-18
	ARACON	12-14	200d/92-95	Unilay	220-400	0.18-0.3	7-9
32	Cu/Ag	9.0-9.6	7/40	Con	106	0.224	2
	CS-95	9.4-10.5	19/44	Con	242	0.256	5.1
	CS-95/Ag	9.4-10.5	19/44	Con	234	0.26	5.1
	Cu/Ni	9.0-9.8	7/40	Con	177	0.231	2
	ARACON	9-10.5	200d/76-88	Unilay	600-1300	0.07-0.12	7-9

Conductance vs. Strength



Termination Performance

Braided Shield

Soldered:

- Good results from Raychem solder sleeve connection.
- Other soldered connections — no problems.

Crimped:

- Excellent results from band-type connectors made by Glenair, Inc.

Conductor

Crimped:

- Preliminary data from Daniels Mfg. Corp. showed consistent pull-out strengths with 22 D contacts with high setting on crimping tool.

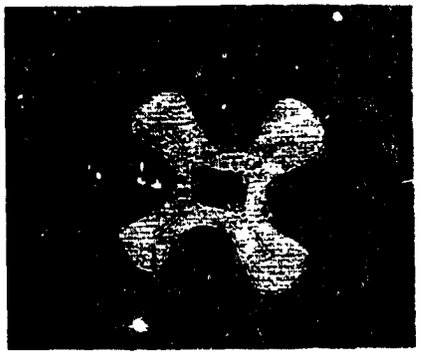
Soldered:

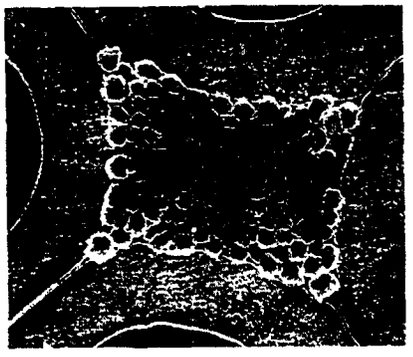
- Data not yet complete, no problems anticipated.

Experience to date shows that ARACON can be terminated utilizing present industry procedures.

Conductor Crimped Termination
400d Based ARACON

Polished Cross Sections
Low and High Magnifications





ARACON Crimp Test Results

Daniels Manufacturing Corporation

ARACON *Yarn Sizes*
- 200d, 400d

Contacts
- Wire Barrel Size — 22D
- M39029/57-354
- Tri-Star Electronics

Tooling
- Tool Frame M22520/2-01
- Positioner M22529/2-06

Results

Denier	Number of Tests	Break Load (lb) Low	High	Avg.	Number of Pullouts	Number Broken at Crimp	Number Broken Outside Crimp
200 (≈32 AWG)	45	3.7	7.0	5.2	0	6	39 (87%)
400 (≈30 AWG)	50	7.2	12.3	9.2	8	0	42 (84%)

Daniels Manufacturing Corporation Conclusions

- ARACON fibers are crimpable and void-free terminations are achievable.
- Strength of crimp is comparable to copper conductors of similar diameter, but with a far greater strength-to-weight ratio.
- ARACON compresses and becomes more dense on crimping, whereas metal extrudes from the crimp joint.
- ARACON is likely to be less sensitive to flex damage.
- There is no evidence of work hardening as with copper.

Safety/Handling/Disposal

- Three-day test during braiding, rewinding for respirables; better than OSHA and DuPont permissible exposure levels.
- Safe to bury or incinerate.
- MSDS sheets available.

ARACON Disposal Recommendation

- Safe to bury.
  - P-aramid is *not* listed as hazardous waste by RCRA.
  - No new hazards for metallic components.
- Incineration OK where allowed for cable.
  - P-aramid can be incinerated.
    - > High carbon yield, low smoke.
    - > Off-gases similar to wool.
- Recyclability?
  - No defined route at this time.
  - Will consider after commercialization.

We do not believe ARACON to be a worse hazard than current cable disposal.

Summary and Conclusions

ARACON -- New technology for conductors and shielding in signal cable.

- *Features:*
  - Greater strength
  - Reduced weight
  - Better flexibility
  - Wide temperature capability
  - Tailored electrical properties
  - High braid coverage with pushback
  - Cables can be made with present equipment
  - Terminates with existing tools
- *Trial test results — better than anticipated plus added benefits observed.*
- *Willing to work with you on new trial installations.*