July 1998

ISSN 1097-7589

Vol. 1 No. 2

Triodyne Inc.

A SAFETY JOURNAL HIGHLIGHTING CRITICAL SAFETY DEVELOPMENTS

SAFETY ALERT

PRICE: $5.00

Swing Gates: The Weak Link in the Chain Link

by Ralph L. Barnett [1] and Patrick M. Brinckerhoff [2]

Abstract

Children are not repelled by barbed wire toppings on chain link fences or gates when the horizontal strands are arrayed in a vertical plane. When childproofing is essential, barbed wire configurations with a 45 degree outward projection are typically used on fences, but not on gates. The persistent use of vertical arrays on gates is confounding since they compromise security and offer no functional advantages. Three gates were constructed for this study to demonstrate the feasibility and characteristics of 45 degree gate toppings.

INTRODUCTION

Two ten year old boys scaled a conventional chain link gate (Figure 1) at an electrical substation leading, as usual, to devastating burn injuries. The substation, which was originally isolated, became contiguous to a park frequented by a general community of children. The perimeter of the protected space was secured by a six foot chain link fabric topped by a three strand barbed wire array deployed on brackets with an outward angle of 45° from the vertical. The double swing gate, as shown in Figure 2, was configured with a standard three strand barbed wire topping disposed in a vertical plane. Although this gate construction meets the appropriate electrical safety code, it is in fact the "weak link in the chain link."

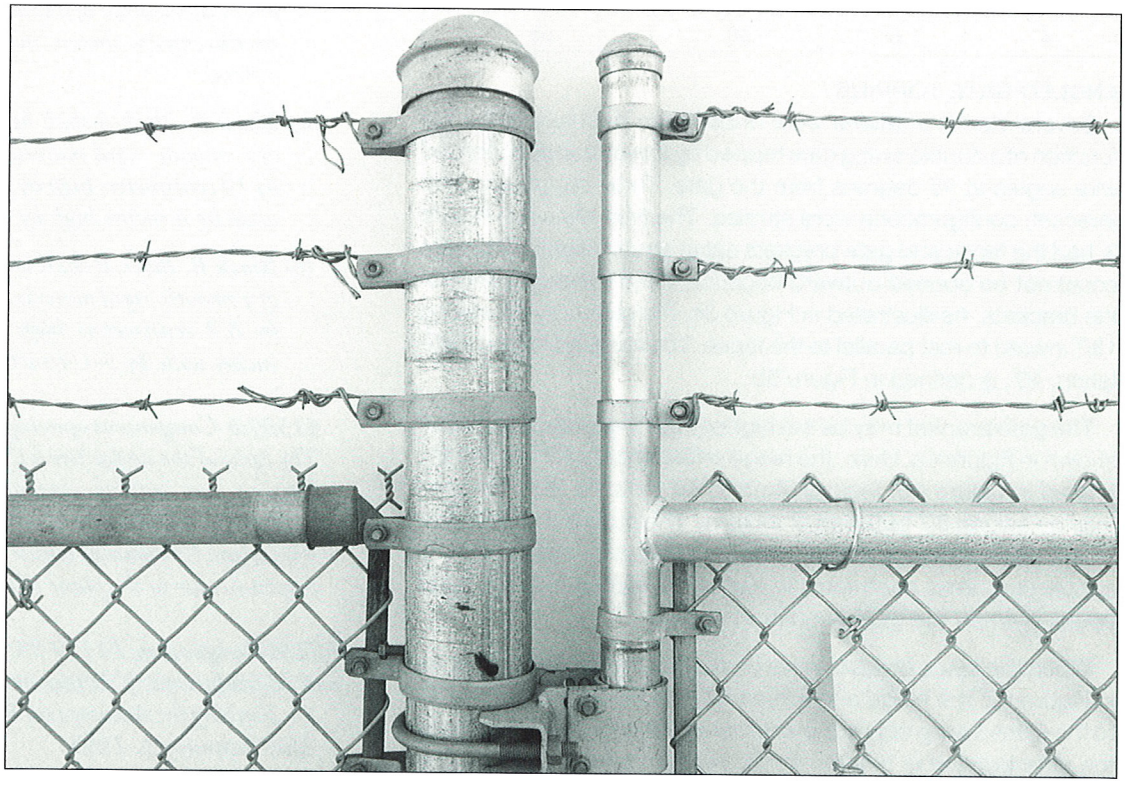


Figure 1. Climbing Zone

[1] Professor, Mechanical and Aerospace Engineering, Illinois Institute of Technology, Chicago, and Chairman, Triodyne Inc., Niles, IL.

[2] Mechanical Engineer, Triodyne Recreation Engineering, Las Vegas, NV.

The vertical barbed wire extension will not prevent children as young as five years old from penetrating the space by climbing over. On the other hand, the 45° barbed wire topping will repel all children that climb unaided. Indeed, both of the injured boys were frustrated in a previous escapade involving a transmission tower secured by the same type of barbed wire system used in the substation perimeter fencing. This paper demonstrates that chain link gates can be effectively hardened using "45° topping" without sacrificing gate function.

CLIMB OVER TESTS

Using the fence illustrated in Figure 2, independent climbing exercises were staged with the four male candidates listed in Table I. Each of the boys chose to scale the fence in the region near the gate post. The 2-inch diamond mesh fabric provides a perfect handhold and foothold for children. The fence was easily climbed by the boys without practice or demonstration; their penetration times are recorded in Table I. Penetration time is defined as the interval from the time the candidate's feet left the ground until the fence was crossed and the candidate's feet touched the ground again. The candidates were unable to scale the fence at the line posts where the fence topping was the standard 45° barbed wire array.

Table I. Penetration Time-Conventional Barbed Wire Array

Candidate	Age (years)	Weight (lbs.)	Penetration Time (sec.)
1	6	48	23
2	5	45	71
3	7	52	37
4	6	36	65

ANGLED GATE TOPPING

Several demonstrations were undertaken to characterize the function of a double swing gate topped by three strands of barbed wire angled at 45 degrees from the gate. Three supporting arm (bracket) configurations were studied. The first, shown in Figure 3, had the fence and gate brackets set at equal heights. The gate could not be opened outward because of interference between the brackets. As illustrated in Figure 3c, the gate may be swung 180° inward to rest parallel to the fence. The required hinge orientation, 40°, is defined in Figure 3b.

The gate bracket may be set higher than the fence bracket as shown in Figure 4a. Here, the hinge orientation is 45° as characterized in Figure 4b. Figures 4c and 4d indicate that the gate may be swung 90° outward or inward. The outward orientation of the gate allows a larger unobstructed gate opening; the supporting arms each intrude about 12 inches into the gate opening when the gate is pushed inward.

When the fence bracket is set higher than the gate bracket as in Figure 5a, the hinge angle illustrated in Figure 5b, 55°, leads to the same swing characteristics described for the case where the gate bracket is higher. In the present case, however, the fence bracket may be projected over the gate bracket in the closed position as shown in Figures 5a and 5b. This minimizes the gap between the two brackets.

PASS THROUGH PENETRATION

Children will attempt to insinuate themselves between the vertical posts associated with the chain link gates. To inhibit this activity, various sources describe the acceptable openings between fence elements:

- *Consumer Product Safety Commission, Part 1509 - Requirements for Non-Full Size Baby Cribs*

  §1509.4 Spacing of unit components.

  (a) Uniformly spaced components. The distance between adjacent, uniformly spaced components (such as slats, spindles, and/or corner posts) shall not be greater than 6 centimeters (2-3/8 inches). The distance between any such adjacent components shall not exceed 6.3 centimeters (2-1/2 inches) at any point when subjected to the test procedure specified in §1509.6.

  (b) Nonuniformly spaced components. (1) The distance between adjacent nonuniformly spaced components (such as slats, spindles, and/or corner posts) shall preclude passage of block A, specified in §1509.5(b), when inserted in any orientation (nonuniformly spaced components refers to irregularly shaped crib slats whether parallel to each other or not).
  (2) The spacing between any such adjacent components shall preclude passage of block B, specified in §1509.5(c), when inserted in any orientation immediately above and below the wedge specified in §1509.5(a) while the components are being subjected to the test procedure specified in §1509.6.

  §1509.5 Component-spacing test apparatus (See Fig. 6).

  (a) Loading wedge. The loading wedge shall be a right triangular prism constructed of a smooth, rigid material conforming to measurements shown in Figure 1 (sides: 12cm, width: 3.8cm).

  (b) Block A. Block A shall be a rectangular block, constructed of a smooth, rigid material, measuring 6 centimeters wide by 10 centimeters high by 10 centimeters long (2-3/8 inches wide by 4 inches high by 4 inches long).

  (c) Block B. Block B shall be a rectangular block, constructed of a smooth, rigid material, measuring 6.3 centimeters wide by 8.2 centimeters high by 8.2 centimeters long (2-1/2 inches wide by 3-1/4 inches high by 3-1/4 inches long).

  §1509.6 Component-spacing test method.
  The apex of the wedge (see §1509.5(a)) shall be placed midway between two vertical components and midway between the uppermost and lowermost horizontal surfaces of the crib side. A 9 kilogram (20-pound) tensile force shall be applied to the wedge perpendicular to the plane of the crib side.

- *ASTM Designation: F1159-94; Standard Practice for the Design and Manufacture of Amusement Rides and Devices*

  14. Fencing for Amusement Rides and Devices Manufactured After January 1, 1993

  14.1 When fences and gates are designed and manufactured to provide protection to spectators and riders, they shall be constructed to meet the following minimum requirements:

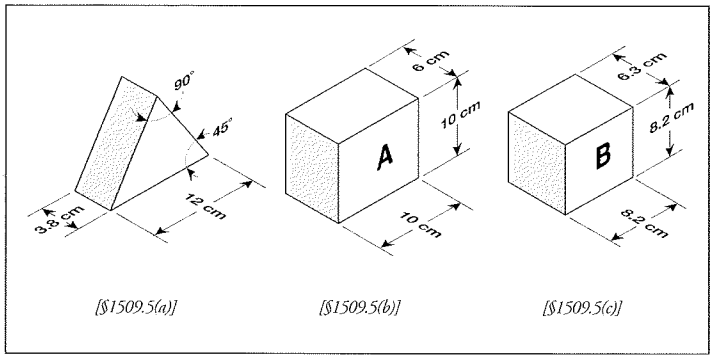


Figure 6. §1509.5

Table II. Head Breadth - Males and Females (inches)

Age (years)	Mean	St'd. Dev.	5th Percentile	Min. Measured
2.0 – 3.5	5.28	0.24	4.92	4.69
3.5 – 4.5	5.39	0.24	5.04	4.88
4.5 – 5.5	5.43	0.20	5.16	4.92
5.5 – 6.5	5.47	0.20	5.16	5.00
6.5 – 7.5	5.55	0.20	5.24	5.00
7.5 – 8.5	5.59	0.20	5.28	5.16
8.5 – 9.5	5.59	0.20	5.20	5.12
9.5 – 10.5	5.67	0.20	5.31	5.00
10.5 – 11.5	5.71	0.20	5.39	5.20
11.5 – 12.5	5.75	0.20	5.39	5.24
12.5 – 13.5	5.79	0.20	5.43	5.28

Table III. Head Breadth - Males (inches)

Age (months)	Mean	St'd. Dev.	5th Percentile
4-6	4.61	0.24	4.21
7-9	4.88	0.28	4.45
10-12	4.96	0.24	4.53
13-18	5.08	0.20	4.65
19-24	5.24	0.16	4.92

14.1.2 They shall be constructed in such a fashion so as to reject a 4-inch ball at all openings.

- *Society of Automotive Engineers, SP-450; Anthropometry of Infants, Children, and Youths to Age 18 for Product Safety Design, 1980*

  If children can fit their heads through parallel bars they can usually pass their bodies through. Table II characterizes head breadth data obtained by SAE from 2686 male and female candidates.

- *Society of Automotive Engineers, SP-394; Anthropometry of U.S. Infants and Children, 1975*

  Table III is taken from data presented by SAE. It represents the statistical characteristics of head breadth measurements obtained from 157 male candidates.

- *Standard Building Code; 1991 Edition, Fourth Printing:*

  1108.5.5 Handrails, where required along open-sided flights of stairs, shall be of construction adequate in strength, durability and attachment for their purpose as prescribed in Chapter 12. They shall include intermediate rails or ornamental patterns such as that a 6-inch diameter sphere cannot pass through any openings.

It would appear that the proper minimum spacing between the chain link gate posts is 4 inches; Table II indicates that no children can breach this spacing. The 2-3/8 inch "crib spacing" is unnecessarily small; on the other hand, the average child can penetrate a 6 inch space.

OBSERVATIONS

1. The American Society for Testing Materials has developed a standard specification for Industrial and Commercial Swing Gates, F900-84. It contains detailed requirements for chain link gates. Barbed wire topping is treated in paragraph 3.2.5 of the standard:

   3.2.5 Barbed Wire Top – When specified, shall have the end members of the gate frame extended in height to accommodate three strands of barbed wire uniformly spaced and positioned so that the top strand is approximately 1 ft. (300 mm) above the top horizontal member of the gate frame. Barbed wire shall be attached by suitable means to prevent wire from moving out of position and shall be supported by a gate frame member at maximum intervals of 8 ft.

   Because of the "shall" language in this paragraph, compliance with this voluntary standard requires that the barbed wire lay in a vertical plane.

   Gate hinges are covered in section 5.2 of the standard:

   5.2 Gate Hinges – Hinges shall be structurally capable of supporting the gate leaf and allow the gate to open and close without binding. The hinges shall be so designed to permit the gate to swing a full 180°. The user shall specify, one of the following directions of swing:
   5.2.1 – 180° outward,
   5.2.2 – 180° inward,
   5.2.3 – 90° in and out.

   We observe that the hinge layouts used in the gates described in Figures 3, 4, and 5 conform to the ASTM standard.

2. The safety of electrical substations is addressed by the IEEE Std. 1127-1990, IEEE Guide for the Design, Construction, and Operation of Safe and Reliable Substations for Environmental Acceptance. This standard conveys the required safety and security philosophy in section 4.8.1:

   4.8 Safety and Security
   4.8.1 Fencing. The primary means of ensuring public safety at substations is by the erection of a suitable barrier, such as a fence. As a minimum, the fence should meet the requirements of ANSI C2.

   Construction guidance may be obtained from ANSI C2-1993, National Electrical Safety Code, section 110:

SAFETY ALERT

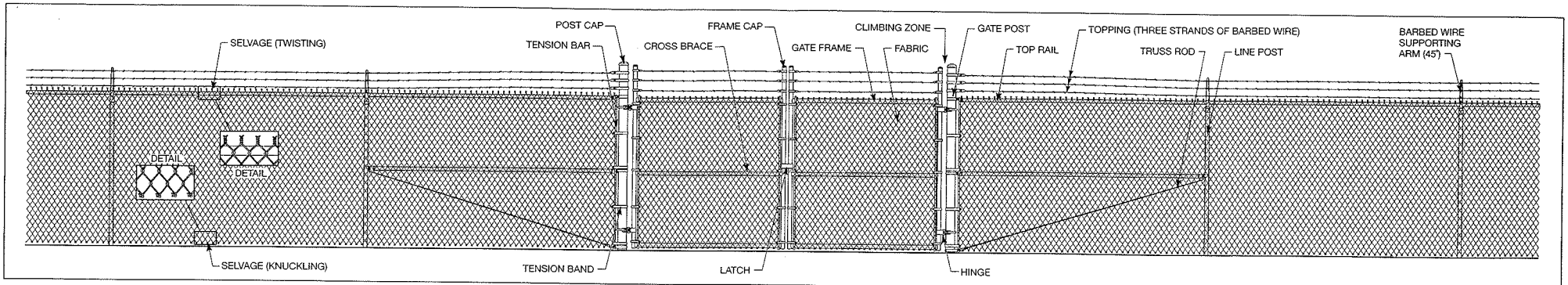
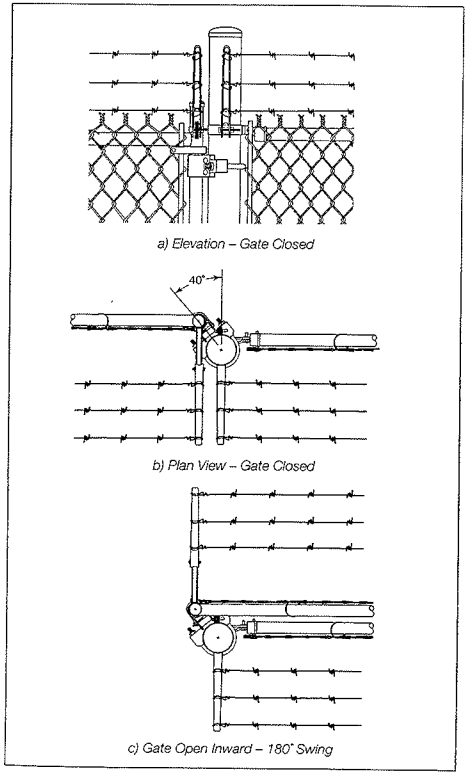


Figure 2. Double Swing Gate

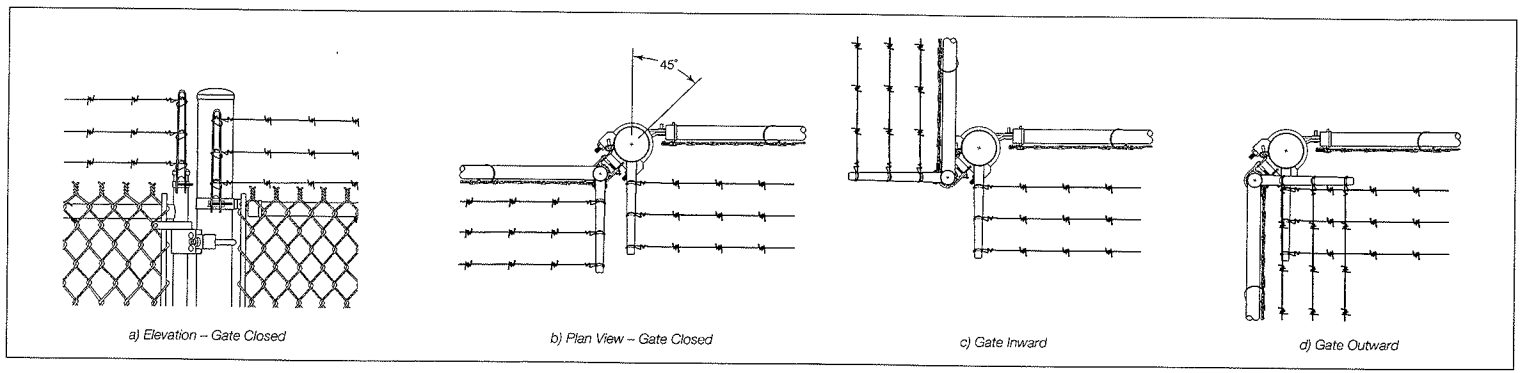


a) Elevation – Gate Closed

b) Plan View – Gate Closed

c) Gate Open Inward – 180° Swing

Figure 3. Equal Height Gate and Fence Brackets



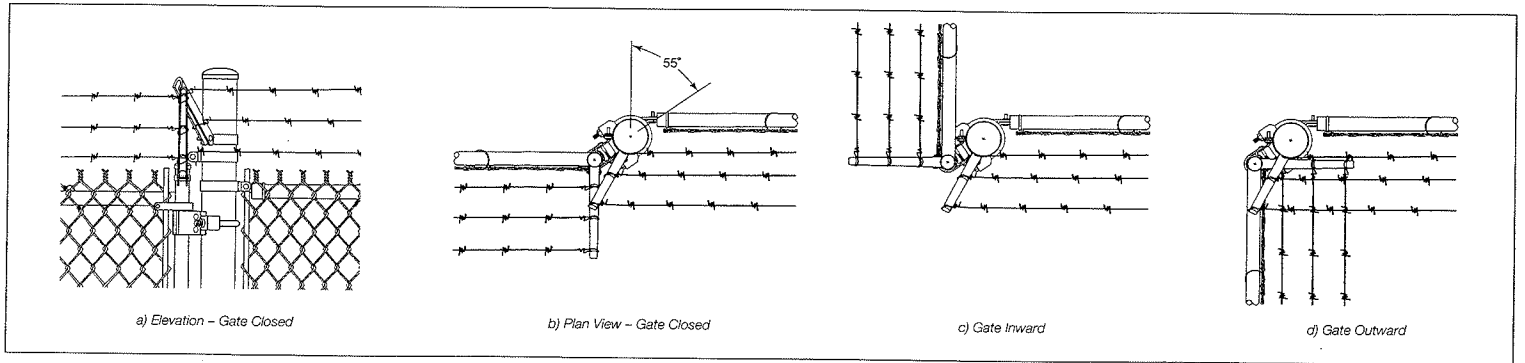
a) Elevation – Gate Closed

b) Plan View – Gate Closed

c) Gate Inward

d) Gate Outward

Figure 4. Gate Bracket Higher Than Fence Bracket



a) Elevation – Gate Closed

b) Plan View – Gate Closed

c) Gate Inward

d) Gate Outward

Figure 5. Fence Bracket Higher Than Gate Bracket

Figure 7. Single Piece Fence / Gate Post

110 General Requirements

A. Enclosure of Equipment

1. Types of Enclosures – Metal fences, when used to enclose electric supply stations having energized electric conductors or equipment, shall have a height not less than 7 ft. (2.13 m) overall and shall be grounded in accordance with Section 9.

The requirements for fence height may be satisfied with any one of the following:

a. Fence fabric, 7 ft. (2.13 m) or more in height.

b. A combination of 6 ft. (1.80 m) or more of fence fabric and a 1 ft. (300 mm) extension utilizing three or more strands of barbed wire.

c. Other types of construction, such as nonmetallic material, that present equivalent barriers to climbing or other unauthorized entry.

Note that requirement (b) allows the barbed wire to be deployed in a vertical array. On the other hand, requirement (c) gives permission to use other more effective forms of protection.

3. The standard chain link hardware used in the fabrication of our three test fences was too flexible to properly tension the barbed wire. We reinforced the standard supporting arms. It is straightforward to fabricate brackets or develop new hardware systems. Furthermore, it is possible to bend the top 14 inches of the gate and fence posts to a 45 degree angle to eliminate the support arms altogether *(See Figure 7)*.

4. Determined adults and trained insurgents can efficiently scale any secured fencing with or without climbing aids. Information on barrier penetration may be found in references 1 and 2.

REFERENCES

1. Fite, Robert A., and Stuart Kilpatrick. 1977. "Final Report - Joint Services Perimeter Barrier Penetration Evaluation," **NBS Special Publication 48C-24.** (November): 75. Gaithersburg, MD: National Institute of Standards and Technology, (formerly National Bureau of Standards).

2. Stanley, Arthur Thomas. 1974. "Barrier Potential of Chain Link Fence," **AD 785-535**, (Report No. 2106). Springfield, VA: National Technical Information Service.

SAFETYALERT

July 1998 Vol. 1 No. 2

AFFILIATED COMPANIES

Triodyne Inc.
5950 W. Touhy Ave.
Niles, IL 60714-4610
Phone: (847) 677-4730
FAX: (847) 647-2047
E-mail: infoserv@triodyne.com
Web: http://www.triodyne.com

Triodyne Fire & Explosion Engineers, Inc.
2907 Butterfield Road
Suite 120
Oakbrook, IL 60521-1176
Phone: (630) 573-7707
FAX: (630) 573-7731

Triodyne Recreation Engineering, Inc.
5950 W. Touhy Ave.
Niles, IL 60714-4610
Phone: (847) 647-9882
FAX: (847) 647-0785

Institute for Advanced Safety Studies
5950 W. Touhy Ave.
Niles, IL 60714-4610
Phone: (847) 647-1101

Alliance Tool & Manufacturing, Inc.
91 East Wilcox Street
Maywood, IL 60153-2397
Phone: (708) 261-1712
FAX: (708) 345-4004

Triodyne-Wangler Construction Company, Inc.
5950 W. Touhy Ave.
Niles, IL 60714-4610
Phone: (847) 647-8866
FAX: (847) 647-0785

Editor: ***Paula L. Barnett***

Illustrated and Produced by
Triodyne Graphic Communication Group