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FINAL REPORT

EVAPORATIVE COOLING GARMENT SYSTEM (ECGS)

PART II

DOUGLAS MISSILE & SPACE SYSTEMS DIVISION

MCDONNELL DOUGLAS CORPORATION

SEPTEMBER 1968

NASA CR 92333

FINAL REPORT

EVAPORATIVE COOLING GARMENT SYSTEM (ECGS)

SEPTEMBER 1968

MDAC-62367

PART II

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WESTERN DIVISION
FOR NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



MISSILE & SPACE SYSTEMS DIVISION

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Appendix A

ECGS PERFORMANCE AND STEAM LINE ANALYSES

ECGS PRELIMINARY THERMAL ANALYSIS

Design Conditions:

Maximum heat load = 500 Btu/hr-ft^2 from body heat

+ 20 Btu/hr-ft^2 from external heat leak

Total = 520 Btu/hr-ft^2

From extrapolated comfort zone data:

Maximum skin temperature = 52°F

Minimum boiler temperature = 35°F

Available working ΔT = 17°F

The required U for the skin contact membrane is:

$$U = \frac{Q}{A\Delta t} = \frac{520}{17} = 30.6 \text{ Btu/hr-ft}^2 \text{ °F}$$

Assuming a membrane thickness of 0.010 in., the membrane thermal conductivity (K) must be:

$$K = Uxt = 30.6 \times 0.010 = 0.306 \text{ Btu/hr-ft}^2 \text{ °F/in.}$$

This K is a minimum value and does not consider the thermal resistance of the membrane-to-skin contact surface, or water to membrane film coefficient.

Water (vapor) evolution rate/ft^2 = $\frac{520}{1040}$ = 0.5 lb/hr at a saturation condition @ 35°F, $P_{\text{water vapor}}$ = 0.09995 psia

Patch area distribution:

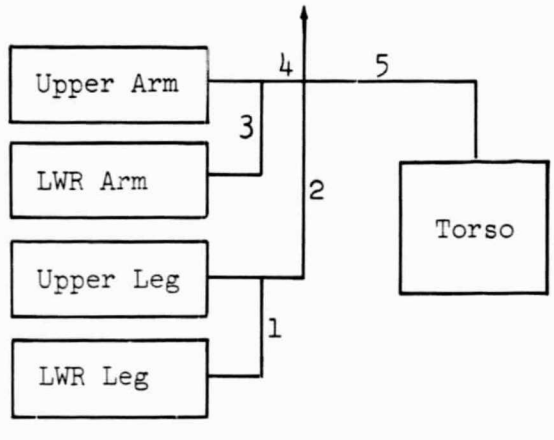
Total Area = 9.8 ft^2

Patch Location	Individual Patch Area (ft^2)	Combined Patch Area (ft^2)
LWR Arm	0.63	1.26
Upper Arm	0.59	1.18
LWR Leg	1.095	2.19
Upper Leg	1.57	3.14
Torso	----	2.03
		*9.80 (total suit)

ine flow requirements:

LWR Arm - 0.63 x 0.5 = 0.315 lb/hr
Upper Arm - 0.59 x 0.5 = 0.295 lb/hr
LWR Leg - 1.095 x 0.5 = 0.5475 lb/hr
Upper Leg - 1.57 x 0.5 = 0.785 lb/hr
Torso - 2.03 x 0.5 = 1.015 lb/hr

Preliminary manifold system:



*Initial full suit area was estimated at 9.80 ft^2. The present design, including the head patch, provides 12.62 ft^2 of cooling area.

Maximum flow in each manifold segment:

Segment Number	Total Flow (lb/hr)	Approximate line length (ft)	ΔP*/L (psi/ft)	ΔP/L (mm Hg/ft)
	CFM			
1	0.5475 (26.9)	0.7	0.000715	(0.037)
2	1.3325 (65.5)	3.5	0.000143	(0.0074)
3	0.315 (15.5)	0.5	0.0010	(0.0518)
4	0.610 (30.0)	2.7	0.000185	(0.00958)
5	1.015 (49.9)	0.5	0.002	(0.1035)
Total	4.900 (241)			

*Based on 0.0259 psi/leg or 0.054 psi to exit

Flow conditions:

P = 0.09995 psia (P' = 5.175 mm Hg)

T = 35°F = 495°R

R = 85.7 ft-lb/lb °R

$$\frac{1}{d} = \frac{\Delta P}{L}\left[(8.7 \times 10^{-6} P'^{.84} S^{1.84})-1\right]^{\frac{1}{4.84}}$$

REF - Kinney Catalog No. 3120 High Vacuum Pipes

Segment Number	ΔP/L (mm Hg/ft)	P (mm Hg)	S (CFM)	$P.^{84}$	$S^{1.84}$	[ ]	d (in.)
1	0.037	5.175	26.9	3.98	327	3.27	0.783
2	0.0074	5.175	65.5	3.98	2185	0.0978	1.616
3	0.0518	5.175	15.5	3.98	155	9.65	0.626
4	0.00958	5.175	30.0	3.98	520	0.532	1.139
5	0.1035	5.175	49.9	3.98	1395	2.27	0.844

STEAM LINE SIZE REQUIREMENTS

Using experimentally determined U of 45.2, calculate line sizes for a range skin temperatures and two metabolic rates.

From heat balance

$$T_B = T_S - \frac{Q}{9.8 \times 45.2} \qquad (1)$$

T_S - Skin temperature

T_B - Boiler temperature

Q - Metabolic rate - Btu/hr (full suit)

Procedure:

1. Select T_S and Q, Q = 5000, Q = 6000, $T_S = 50^\circ - 70^\circ$, $T_S = 35^\circ - 60^\circ$ (5° increments).
2. Calculate T_B from Equation 1.
3. From steam table, get Vg, h_{fg}, and P at T_B
4. Calculate W_w/ft^2 (water flow/ft^2 of patch surface) from

$$W_w/ft^2 = \frac{Q}{h_{fg} \times 9.8}$$

Vg - Vapor specific vol-ft^3/lb

h_{fg} - Heat of vaporization Btu/lb

P - Saturation pressure at T_B psia

5. Get individual manifold line flows from:

$W_{w_1} = 1.095 \times Ww/ft^2$ $\qquad$ $W_{w_4} = 1.22 \times Ww/ft^2$

$W_{w_2} = 2.665 \times Ww/ft^2$ $\qquad$ $W_{w_5} = 2.03 \times Ww/ft^2$

$W_{w_3} = 0.63 \times Ww/ft^2$

6. Calculate S_1 through S_5 from $S_n = W_{w_n} \times Vg/60$ (CFM).

7. Calculate P' (mm Hg) from P' = 51.8 x P (psia)

8. Calculate d_1 through d_5 from

$$d_n = \left[\frac{8.7 \times 10^{-6} \times (P')^{.84} \times S_n^{1.84}}{\left(\frac{\Delta P}{L}\right)_n} \right]^{\frac{1}{4.84}}$$

Where d_n is duct I.D. in.

$$\left(\frac{\Delta P}{L}\right)_1 = 0.037$$

$$\left(\frac{\Delta P}{L}\right)_2 = 0.0074$$

$$\left(\frac{\Delta P}{L}\right)_3 = 0.0518$$

$$\left(\frac{\Delta P}{L}\right)_4 = 0.00958$$

$$\left(\frac{\Delta P}{L}\right)_5 = 0.1035$$

See Figures 1 and 2 for calculated diameters.

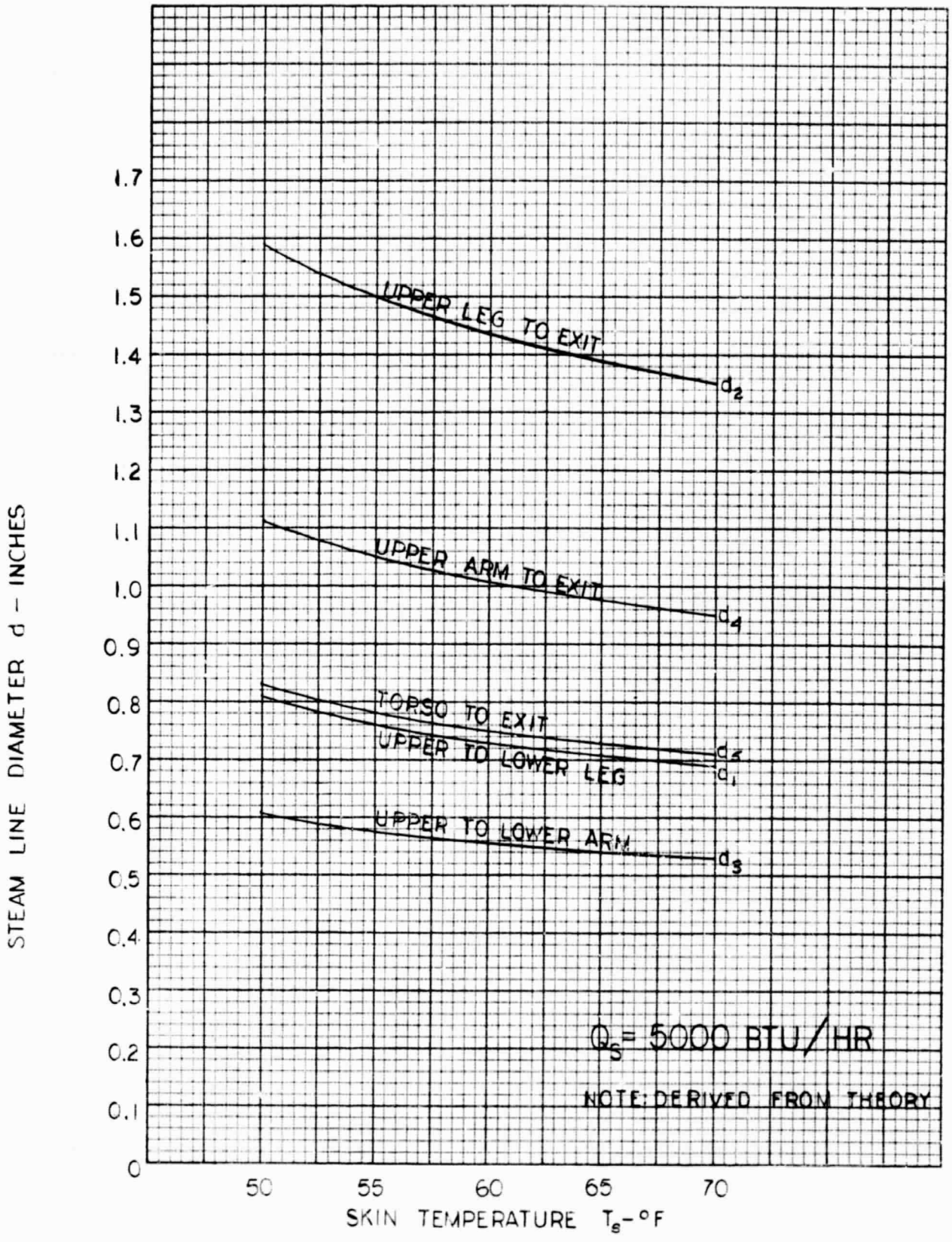


Figure 1. ECGS Steam Line Size vs Skin Temperature

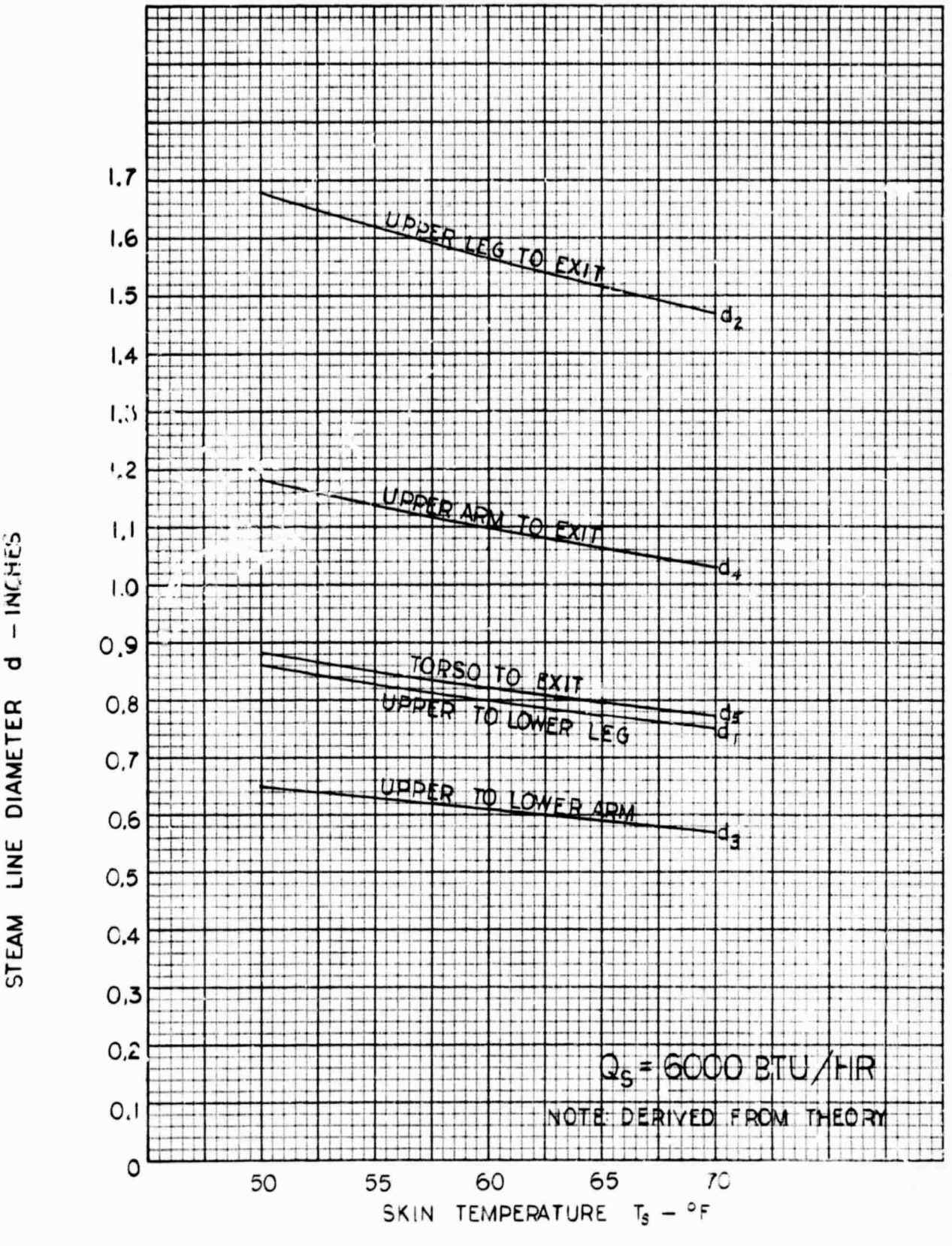


Figure 2. ECGS Steam Line Size vs Skin Temperature

MAXIMUM NATURAL BODY COOLING

Assumptions:

5 mph wind-70°F air-40% relative humidity

Skin surface temperature = 95°F (=sweat temperature)

Vapor pressure of sweat at 95°F = 0.8153 psia

Vapor pressure of water in 70°F-40% relative humidity air is = 0.2220 psia, V_g = 867.9 ft^3/lb

Saturated air at 75°F (assumed air ΔT in passing over body) = P_{H_2O} = 0.3631 V_g = 740 ft^3/lb

Water evaporated by each ft^3 of air

$$W_{evap} = \frac{1}{740} - \frac{1}{867.9} = 0.000199 \text{ lb/ft}^3$$

Assume 1-in.-thick blanket of air reacts:

Body surface area = 20 ft^2, also the air travels 2 ft over the body surface at 5 mph = 7.33 ft/sec.

Therefore the swept volume is changed every 2/7.33 sec = 0.273 sec.

Swept volume = (20 x 1)/(12) = 1.667 ft^3

Water evaporated = 0.000199 x 1.667 = 0.000332 lb/sec.

This is equivalent to a body heat loss by evaporation of sweat of:

q_{sweat} = 0.000332 x 1050 x 3600 = 1255 Btu/hr

The heat loss by convection can be calculated as follows:

Assume h_c = 5 Btu/hr - ft^2 - °F

$q_c = hA\Delta t$ = 5 x 20 x 20 = 2,000 Btu/hr

Total heat loss = 2,000 + 1,255 = 3,255 Btu/hr

Appendix B

ECGS BOILER VOID PRESSURE-DROP ANALYSIS

The boiler void material was tested to determine its pressure loss characteristics under a range of flow conditions. The tests were made using air as the working fluid. In order to use the test results in the ECGS application, it was necessary to operate on the test data to put it in a form which was not dependent on a specific fluid. This was done by plotting the data as modified Reynolds number vs. flow loss coefficient. The Reynolds number was defined as conventional Reynolds number using the material thickness as the characteristic dimension and the total material cross-section perpendicular to flow as the flow area. Then

$$R_e' = \frac{W\,D}{A\,\mu}.$$

where

W = flow of gas - lb/hr

D = material thickness - ft

A = flow cross-section (as described above) - ft^2

μ = gas viscosity lb/hr-ft

The flow loss coefficient was defined as the fraction of the dynamic pressure (q) lost per unit flow length. Then

$$K = \frac{\Delta P \times 2g\,(P_1 - \frac{\Delta P}{2})}{RTL}\left(\frac{A}{W}\right)^2$$

where

ΔP = pressure loss through Trilock--psi

P_1 = upstream total pressure--psi

g = acceleration of gravity--32.2 ft/sec^2

R = gas constant--ft lb/lb-$^{\circ}$R

T = gas temperature--$^{\circ}$R

L = flow length--in.

A = total material cross-section perpendicular to flow--in.^{2}

W = gas flow rate--lb/hr

Using the above relationships the test data was reduced to a form that can be used with any gas which obeys the perfect gas law. Water vapor at low temperatures and pressures, such as that found in ECGS patch operation, satifies this requirement as long as no condensation occurs. ECGS operation is such that the vapor is heated and reduced in pressure continuously after it is first evaporated so no condensation occurs.

Appendix C
BIOCHEMICAL RESPONSES TO EXERCISE

INTRODUCTION

Muscle requires a continuing energy supply for normal excitability and mechanical behavior. From measurements of the heat produced during muscular contraction, it has been established that energy is liberated in two major stages. A small amount of heat is given off upon contraction and a larger amount of heat is liberated for many seconds, or even for several minutes, after contraction. Initial heat is evolved during glycolysis, and the large later heat is evolved during the complete combustion of lactic acid to carbon dioxide and water. Decomposition of ATP to ADP is the immediate source of energy; ADP is "recharged" to ATP by glycolysis, during which glucose is decomposed to pyruvate (or lactate in the absence of sufficient oxygen, and by oxidation of pyruvate to CO_2 and H_2O in the reactions of the Krebs cycle).

The efficient progression of these biochemical mechanisms during muscular contraction is dependent, in part, on heat production, removal, and its effects on enzymic reactions. Muscle efficiency and work output increase with temperature, but will eventually reach a period of inefficiency due to accumulation of excess heat.

As an adjunct to present skin temperature studies during high metabolic output, a preliminary test was conducted (under Douglas IRAD program) to determine what the muscular biochemical response was prior to, during, and after exercise.

MATERIALS AND METHODS

The subject was 20 years old, weighed 160 lb, and was 5 ft 11 in. tall. His right arm was enclosed in a typical arm cooling garment. (However, no cooling was utilized during this test.) The subject exercised his arm and hand by compressing a sphygmomanometer bulb. This created pressure to maintain specified pressures and the pumping of gas flow through a calibrated flow meter,

thus measuring the work output. The constant bulb compression energy is additive to the work function. Most of the muscular energy was used to compress the bulb, as the rebound characteristics made the muscular relaxation phase almost passive. Temperature probes were placed on the exercised (right) arm and the nonexercised (left) arm.

Blood was drawn from the basilic vein of the right arm; 5 cc was immediately placed in 7-1/2 percent perchloric acid (for pyruvic and lactic acid determinations), 4 cc was placed in a tube containing sodium oxalate and sodium fluoride. The remaining blood was placed in a clean, sterile tube for clotting and subsequent removal of serum. All determinations were performed by a qualified independent clinical laboratory. Samples were drawn before exercise, during different phases of exercise, and after exercise.

The results of analyses are shown in Figure 3. A gradual decrease from 90 mgm percent to 74 mgm percent in glucose was noted as exercise continued. An initial fall in lactic acid upon initiation of exercise was followed by a rise toward the fatigue point. By 1 hour after the cessation of exercise, the lactic acid returned to normal. Pyruvic acid fell during exercise, returning to above normal 1 hour after exercise. Glutamic oxalacetic transaminase was normal in all measurements, while glutamic-pyruvic transaminase rose from 25 to a high of 47 at the fatigue point, and did not return to pre-exercise values 1 hour after exercise.

DISCUSSION

This relatively simple experiment indicates that it is possible to correlate heat output with biochemical changes evolving during muscular exercise. If additional contract funding were available, more comprehensive studies could be made.

Further research in biochemical analysis during optimum cooling with the efficient controllable and rapid response cooling as provided by the ECGS system could include additional enzyme studies, for example, the CPK (creatine phosphokinase, creatine kinase or ATP-creatine phosphotransferase) (Reference 1). Bedrack, Beer, and Furman (Reference 2) have shown that the fibrinolytic activity

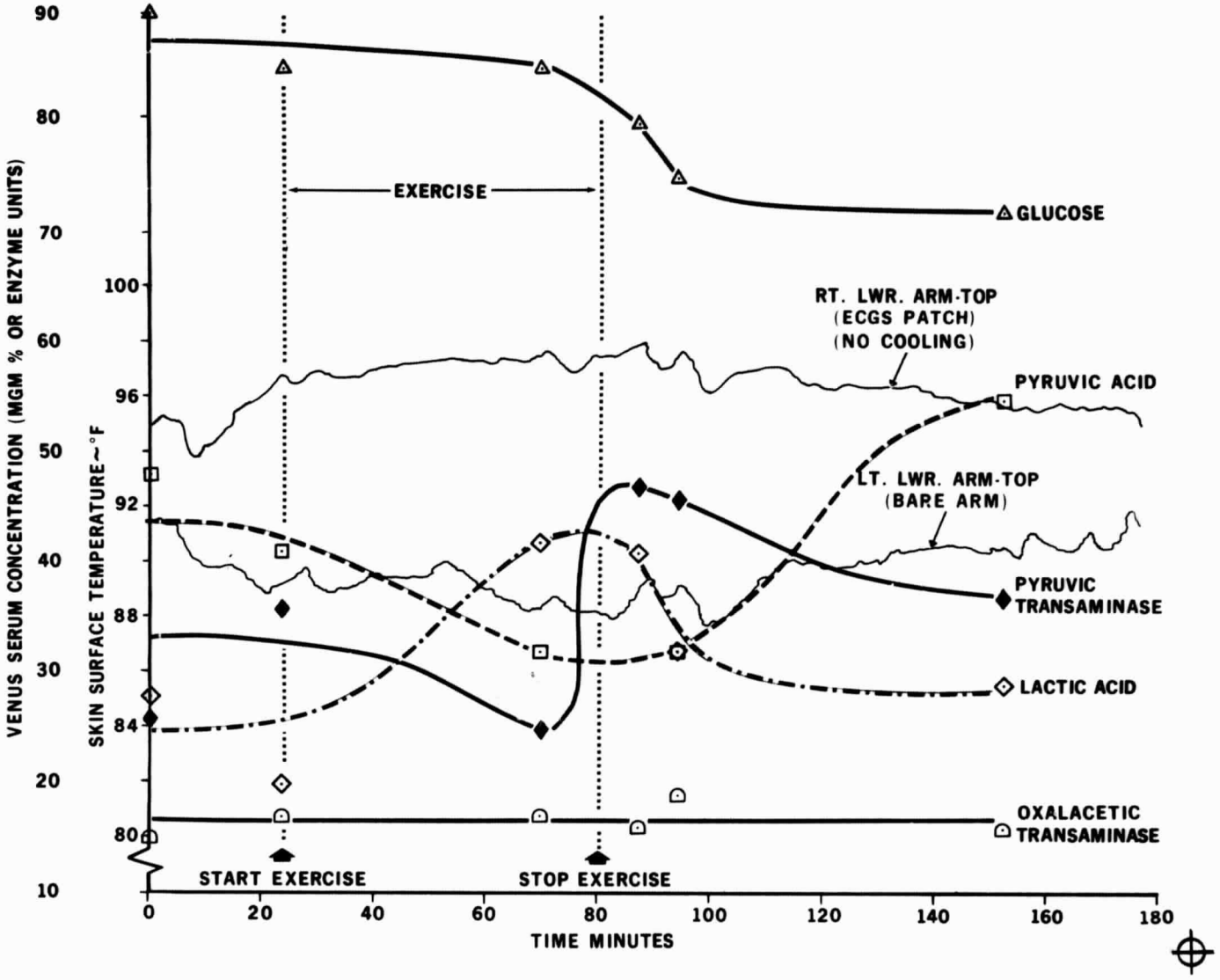


Figure 3. Effect of Exercise on Biochemistry of Muscle

of whole blood is increased by exposure to environmental heat stress, the increased activity being similar to that which accompanies strenuous exercise.

It is postulated that biochemical techniques, such as described, could establish a programmed cooling rate which would enhance an astronaut's ability to perform high-energy sustained work loads.

REFERENCES

1. J.H. Hess, Enzyme Tests in Clinical Situations. Lab World, September 1967, Page 1000.

2. E. Bedrak, G. Beer, and K.I. Furman. Fibrinolytic Activity and Muscular Exercise in Heat. Journal of Applied Physiology, Vol. 19, No. 3, May 1964.

Appendix D

ECGS STEAM LINE PRESSURE DROP EFFECTS ON OVERALL SYSTEM PERFORMANCE

In order to determine the pressure required at the steam collector for each ECGS patch, a heat balance gives:

$$T_p = T_s - \frac{Q}{AU} \tag{1}$$

where: $\Delta T = T_s - T_p$

A value of 40 Btu/hr-ft^2 °F for U has been found experimentally to closely describe patch heat transfer. Substituting for ΔT and solving for T_p gives:

From a steam properties table, the saturation pressure at T_p can be obtained (P_p). This then is the pressure in the patch at the skin temperature and heat removal rate in question.

The steam flow can be obtained from:

$$Q = W\Delta h_{fg}$$

$$W = \frac{Q}{\Delta h_{fg}}$$

At the conditions existing under ECGS patch operation Δh_{fg} is fairly constant at 1,050 Btu/lb. Therefore:

$$W = \frac{Q}{1050} \text{ or } \left(\frac{Q}{A}\right) \times \frac{A}{1050} \tag{2}$$

Having defined T_p, P_p and W, the pressure drop and consequently the pressure at the exit for each patch steam line can be calculated from:

$$\Delta P = \left(f \frac{\ell}{D} + K\right) \left(\frac{W}{A}\right)^2 \frac{RT_p}{2gP_p} \tag{3}$$

From tests run on samples of the corrugated WTF flex steam line the maxium f was found to be about 0.15. The value of 1.5 will be used for K to allow for entrance - exit, and internal patch losses. This value will be used for all calculations, even though it may be slightly high, it will give conservatively high pressure drops. The steam line exit pressure or collector manifold pressure (P_e) can be obtained from:

$$\Delta P = P_p - P_e$$

$$P_e = P_p - \Delta P$$

Substituting for ΔP from equation 3 gives:

$$P_e = P_p - \left[\left(f\frac{\ell}{D} + K\right)\left(\frac{W}{A}\right)^2 \frac{RT_p}{2gP_p}\right] \qquad (4)$$

Using equations 1, 2, and 4 the collector pressure was calculated for each patch. The results of these calculations are shown in Figures 4 and 5.

DEFINITION OF TERMS

A - patch surface area
D - steam line inside diameter (0.50 inches)
f - pressure drop friction factor
g - acceleration of gravity (32.2 ft/sec^2)
K - pressure drop loss coefficient
ℓ - steam line length
P - pressure
R - gas constant for water vapor (85.7 ft-lb/lb-°R)
T - temperature
U - overall heat transfer coefficient
W - steam mass flow rate

SUBSCRIPTS

ρ - ECGS patch internal conditions
ε - steam line exit conditions

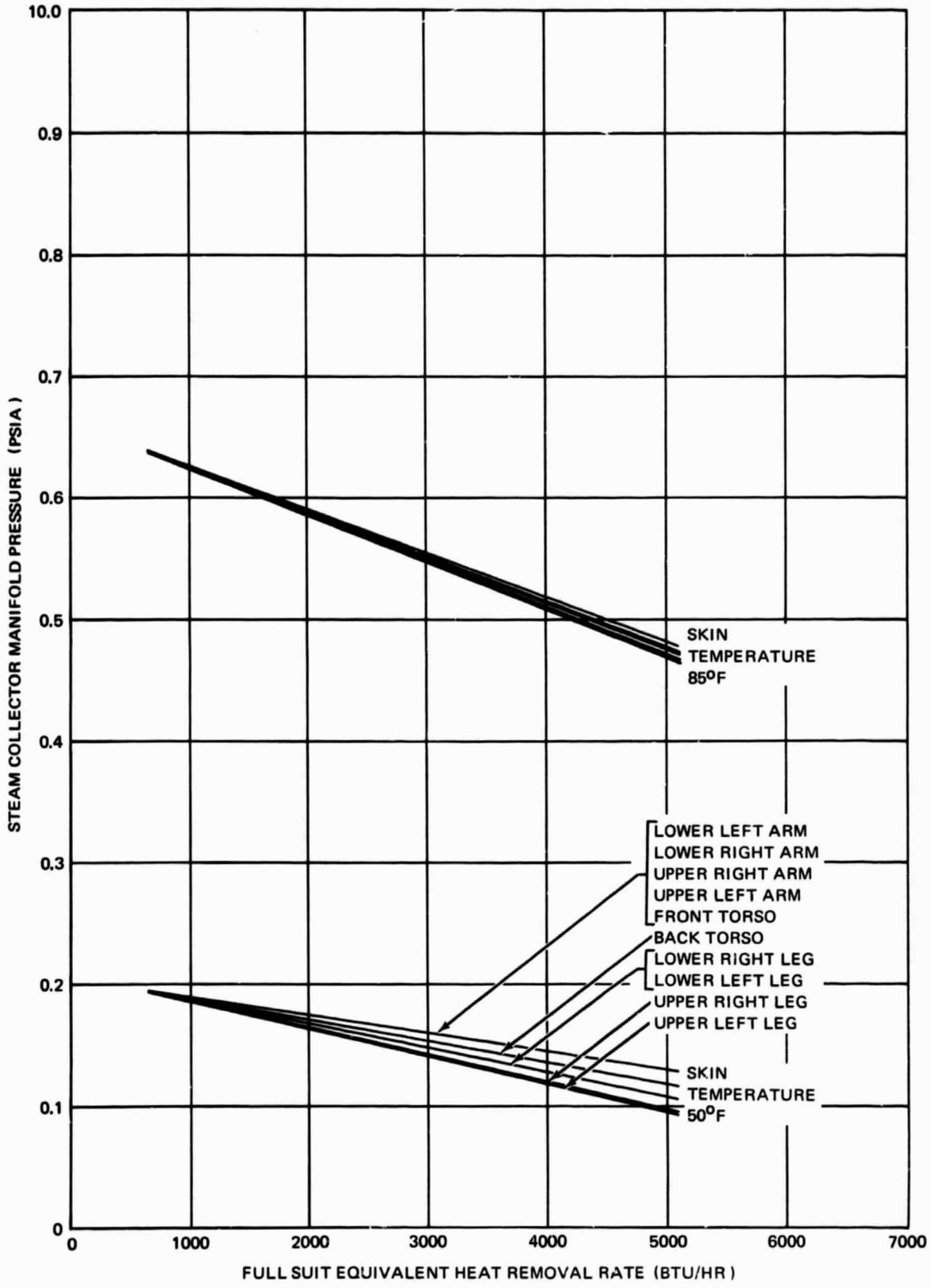


Figure 4. Steam Collector Pressures

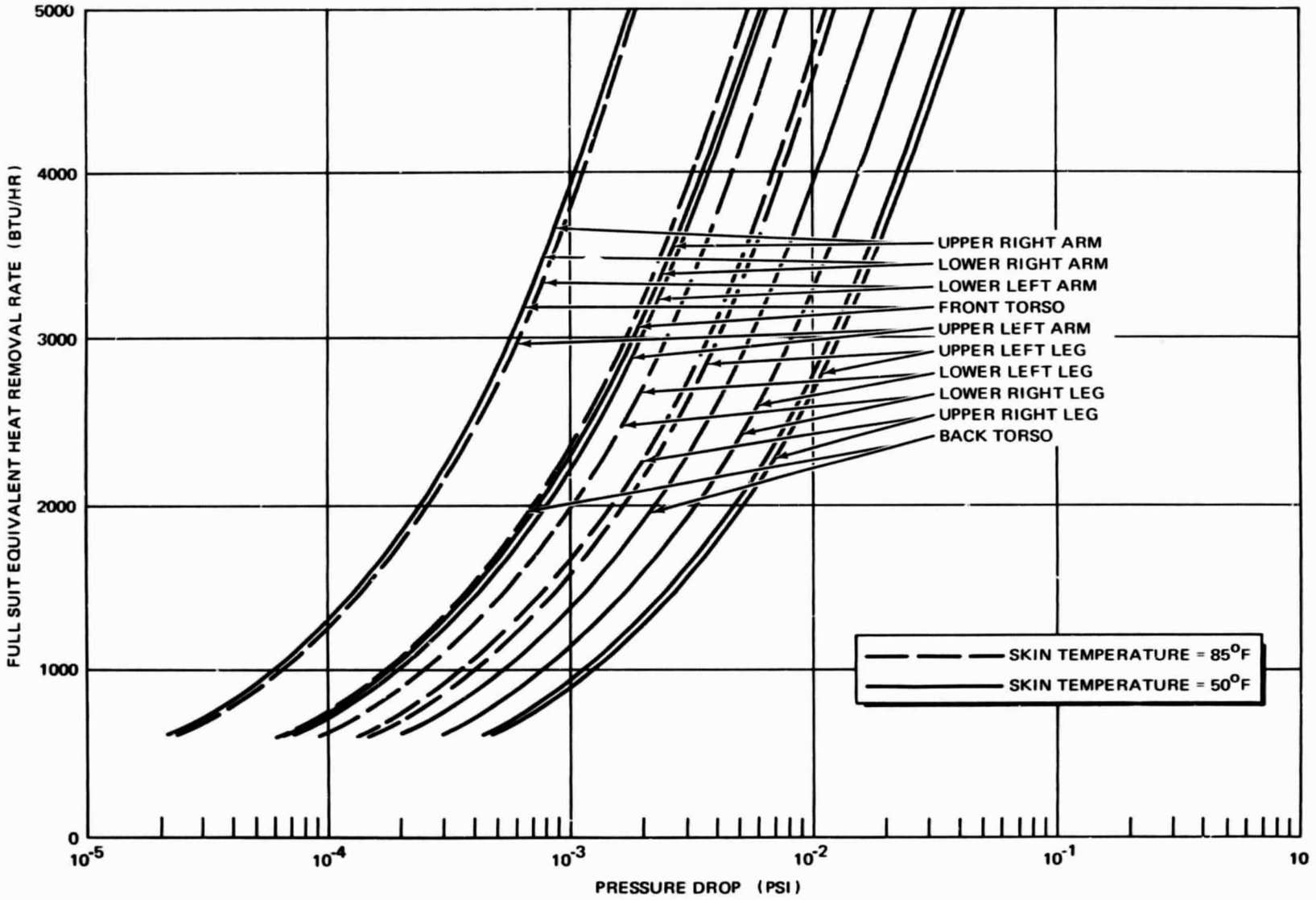


Figure 5. ECGS Steam Line Pressure Drop

Appendix E

COMPLETE DATA RESULTS ON A TYPICAL DESIGN VERIFICATION TEST RUN

The following plots are typical reduced data from the Design Verification tests, and are representative of the information collected. These data have been analyzed, along with other tests and the summarized information therefrom are presented in the Volume I report.

PRELIMINARY TEST RESULTS
Run #600, 601, and 602
June 7, 1968

Test Configuration

Full ECGS with head piece
Subject J.B. (subject #1)
Treadmill speed 0 mph, grade 0%
Metabolic rate--400 Btu/Hr.

Instrumentation

19 thermisters located as follows:
2 under each patch except lower left arm
1 on left forehead
22 pressures--2 in each patch

Test Objective

To find the heat removal rate required for thermal equilibrium.

Test Results

Run times--18.6, 30.0, 30.0 minutes
Heat removal rates--200, 300, 400 Btu/Hr
Subject felt too cool at 300 and 400 Btu/Hr heat removal rates, and not cool enough at 200 Btu/Hr. Suggests 250 Btu/Hr would be optimum for this subject;

Time vs. skin temperature plots are attached. They show the increase in cooling as the heat removal rate is increased. Thermal stability is evidenced by a steady-unchanging skin temperature.

Comments

The subject felt uniformly cool and relatively comfortable during all three runs. Temperature measurements were made at all locations listed in "instrumentation", but some were not plotted due to recording difficulties.

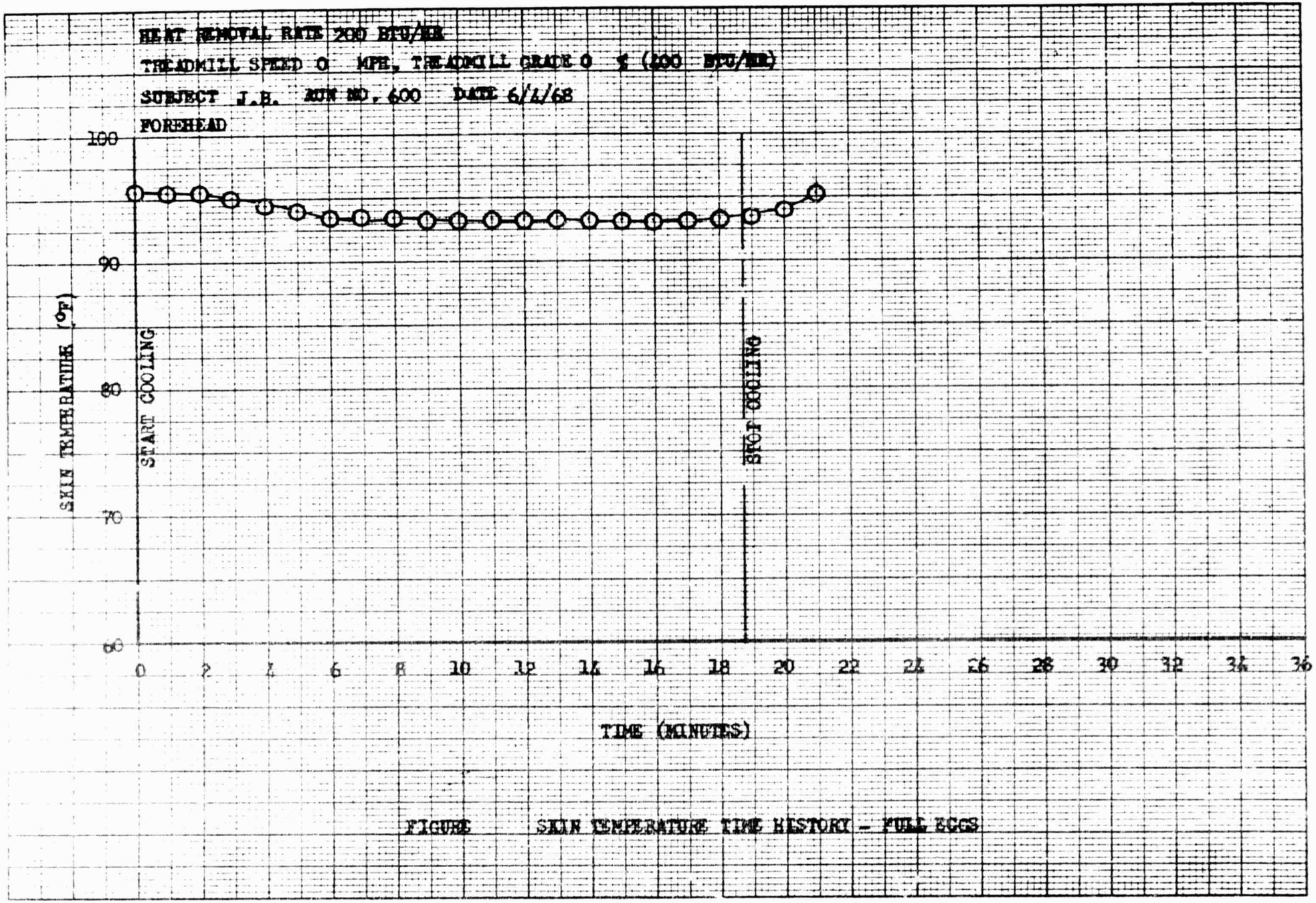


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

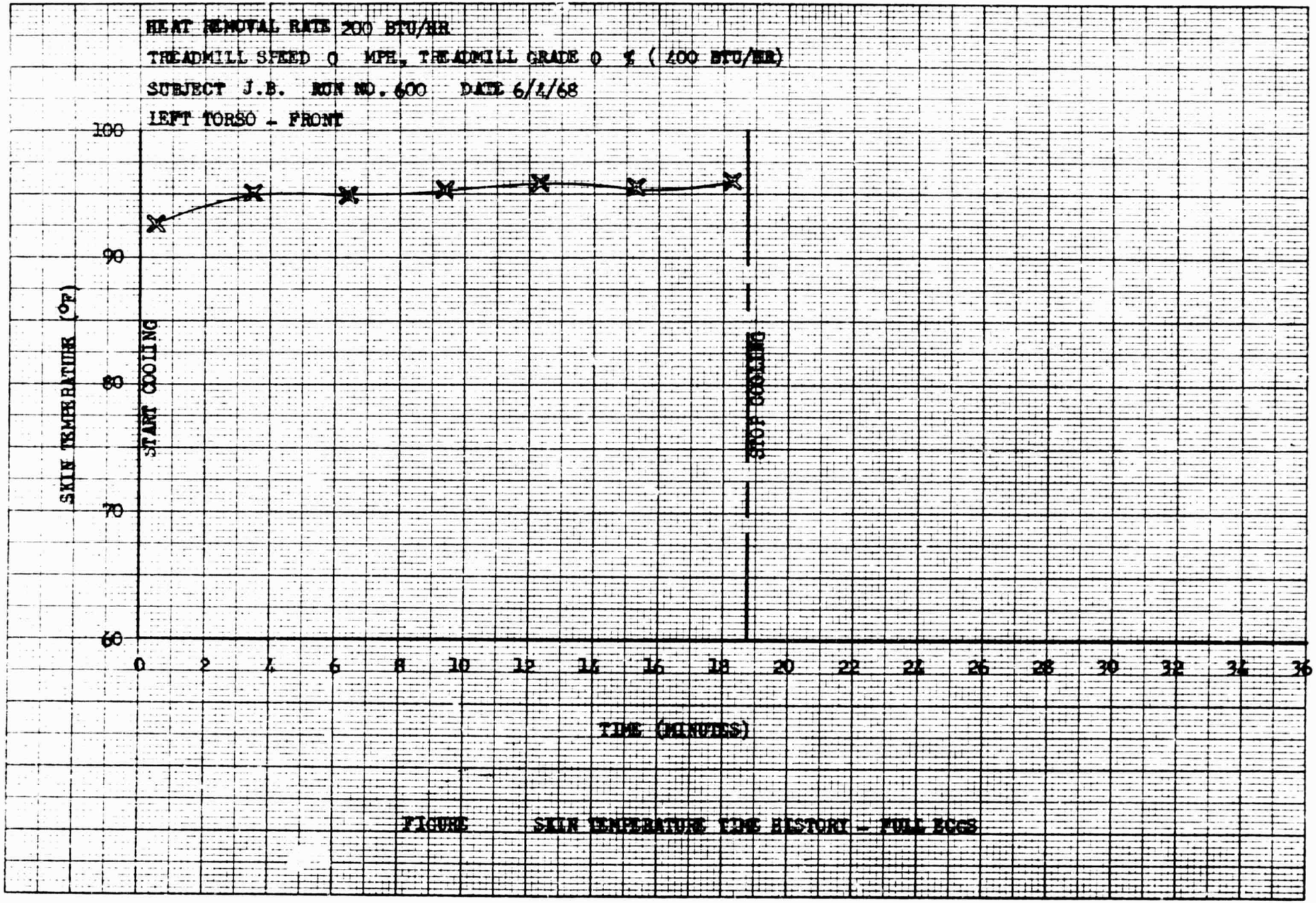


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL EGGS

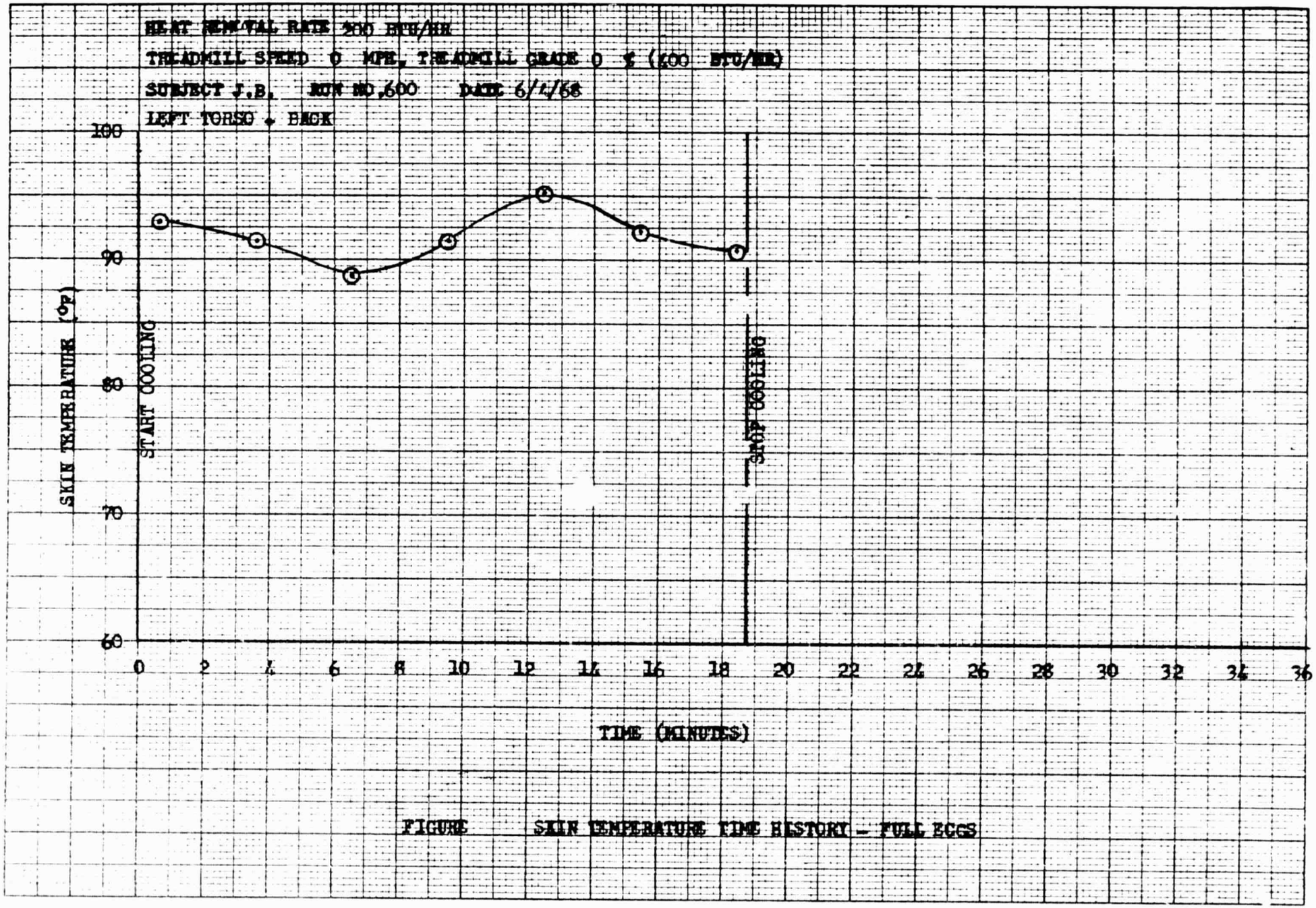


FIGURE SKIN TEMPERATURE TIME HISTORY – FULL EGGS

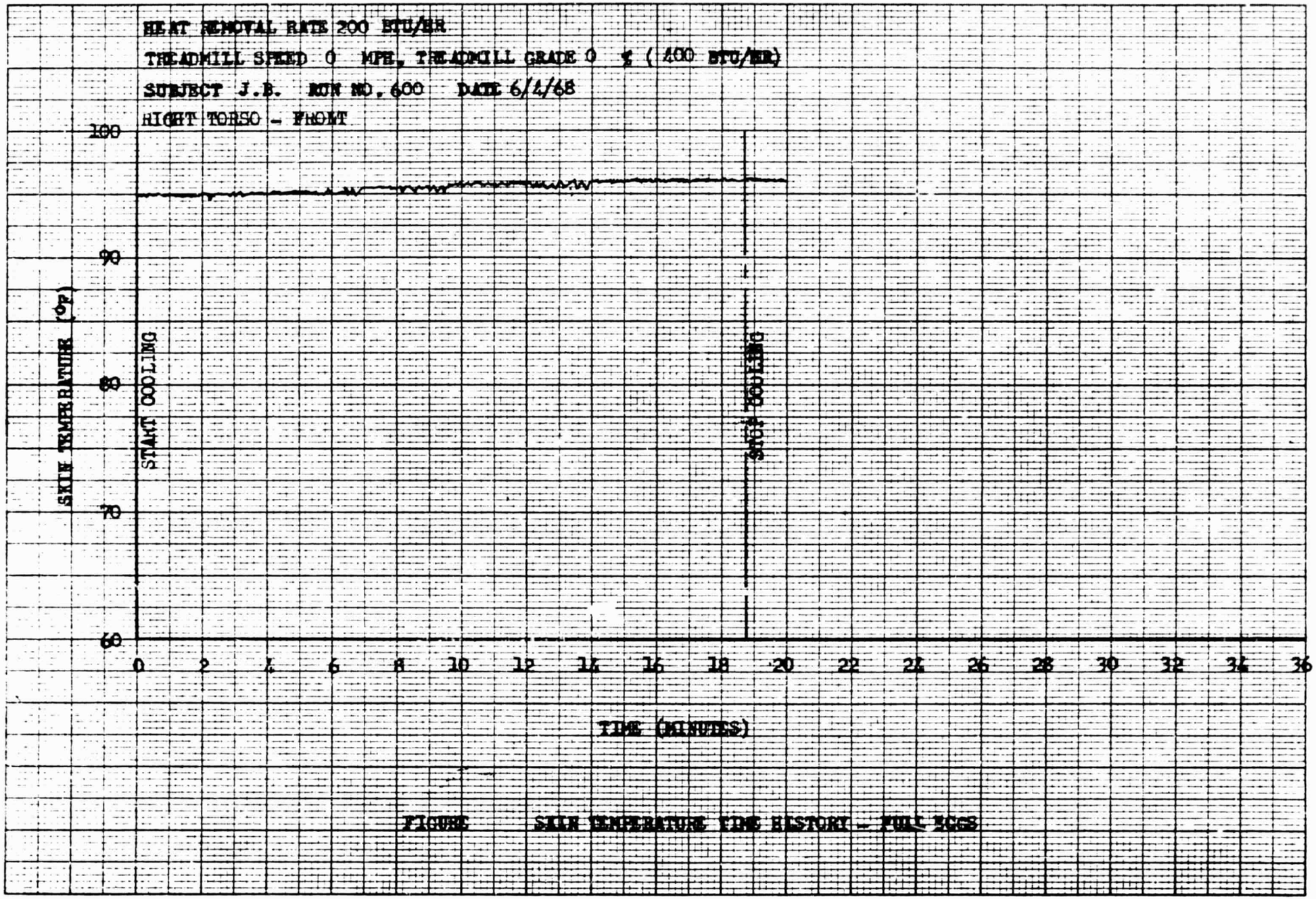


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ICGS

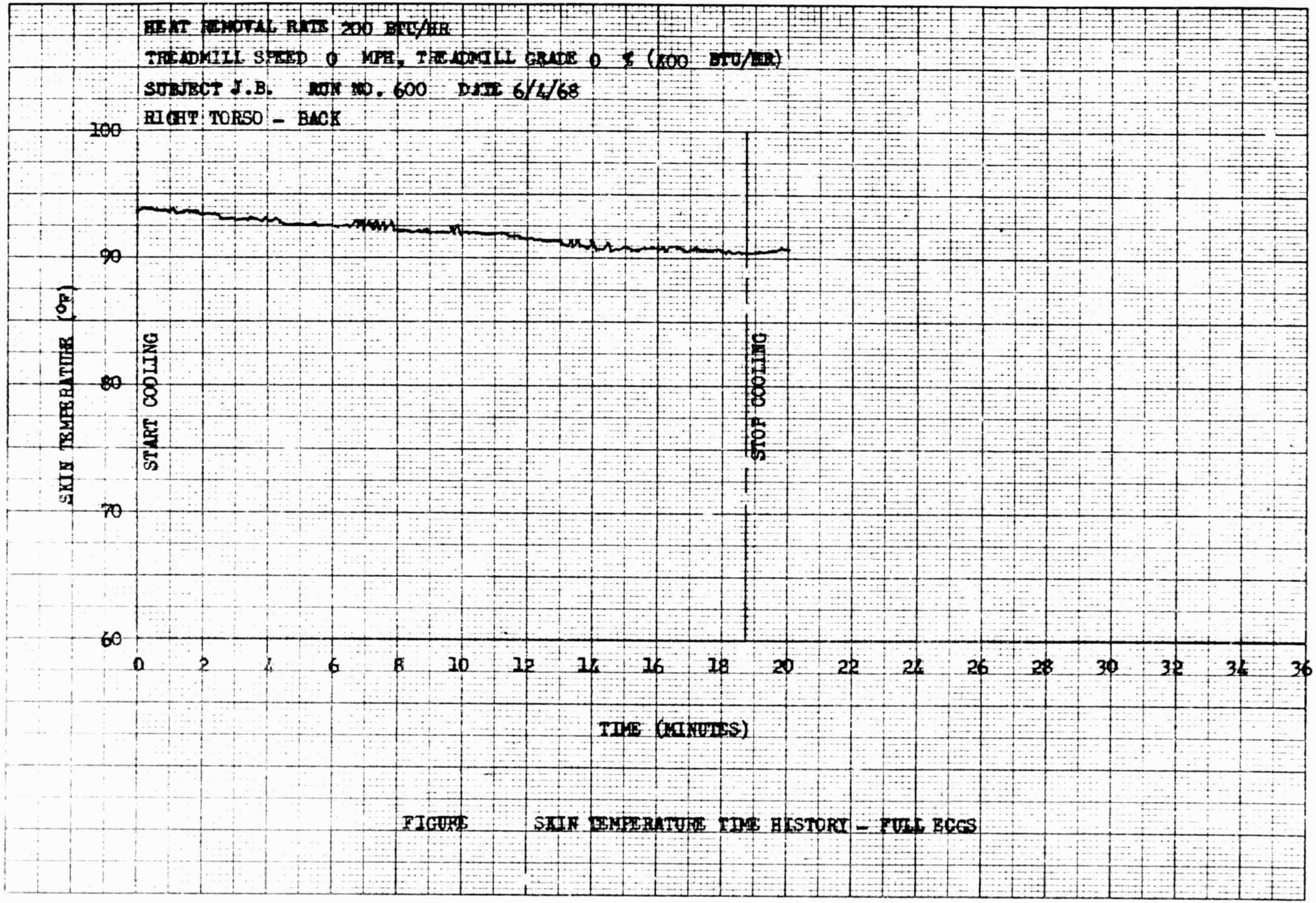


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

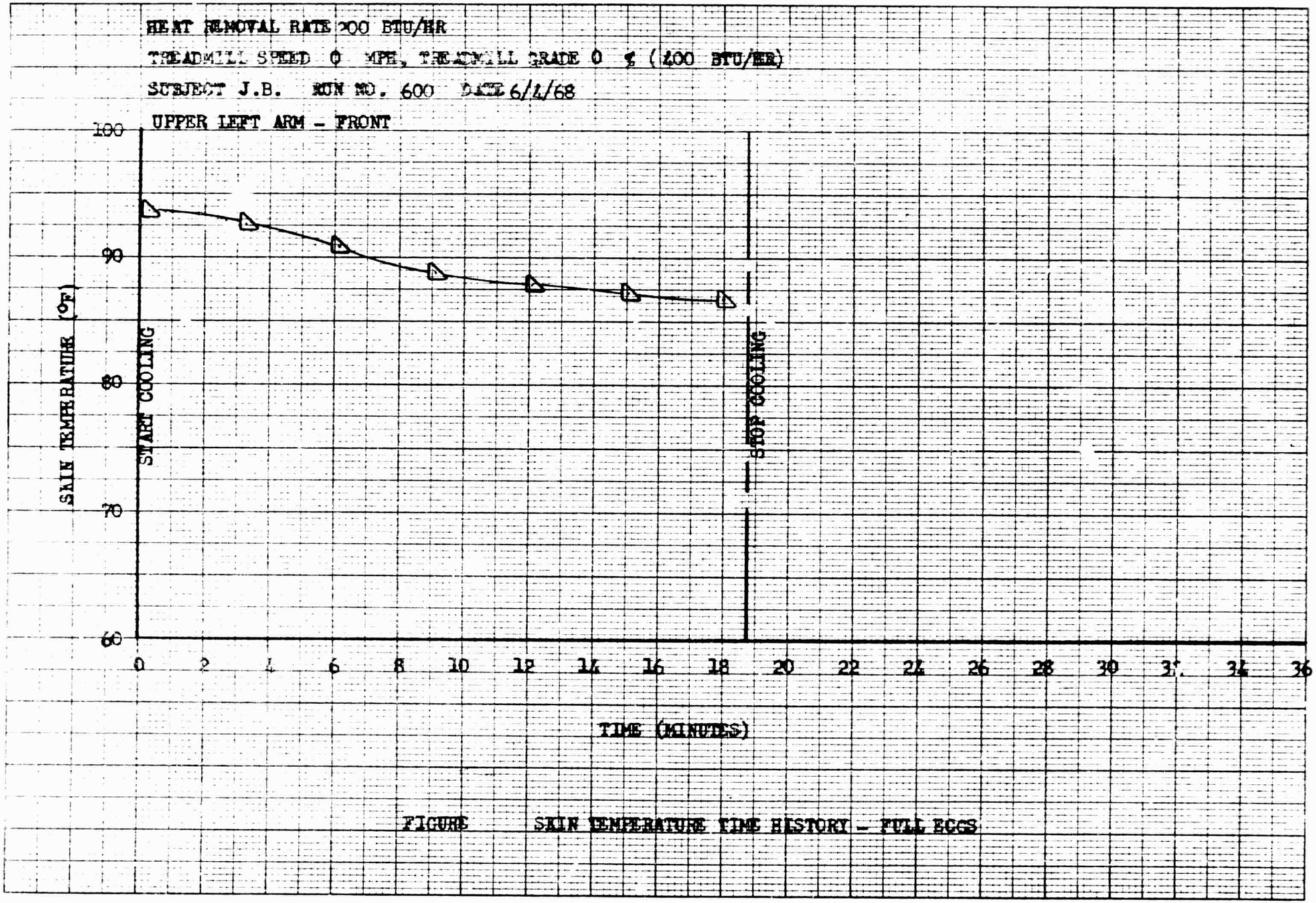


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

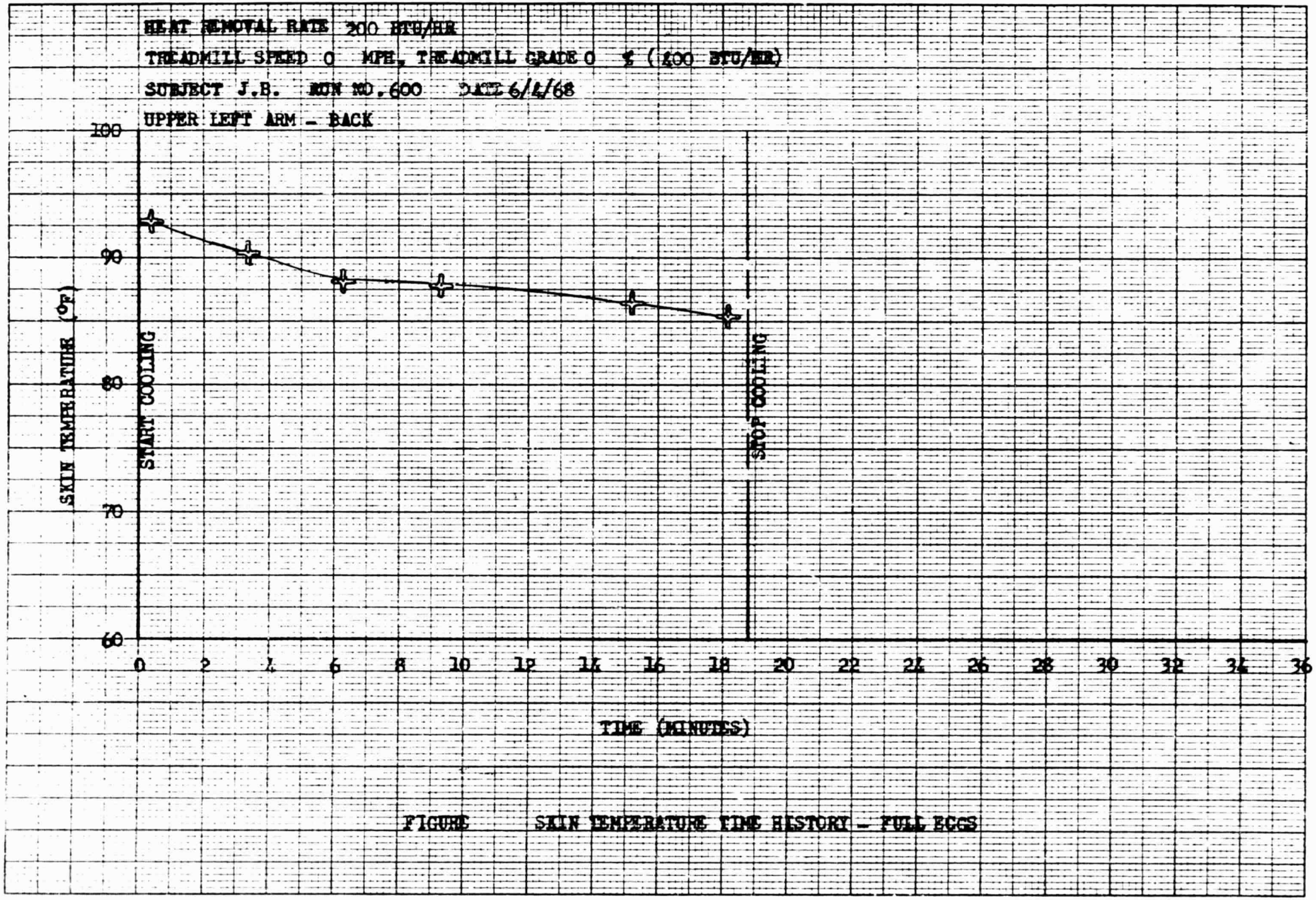


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

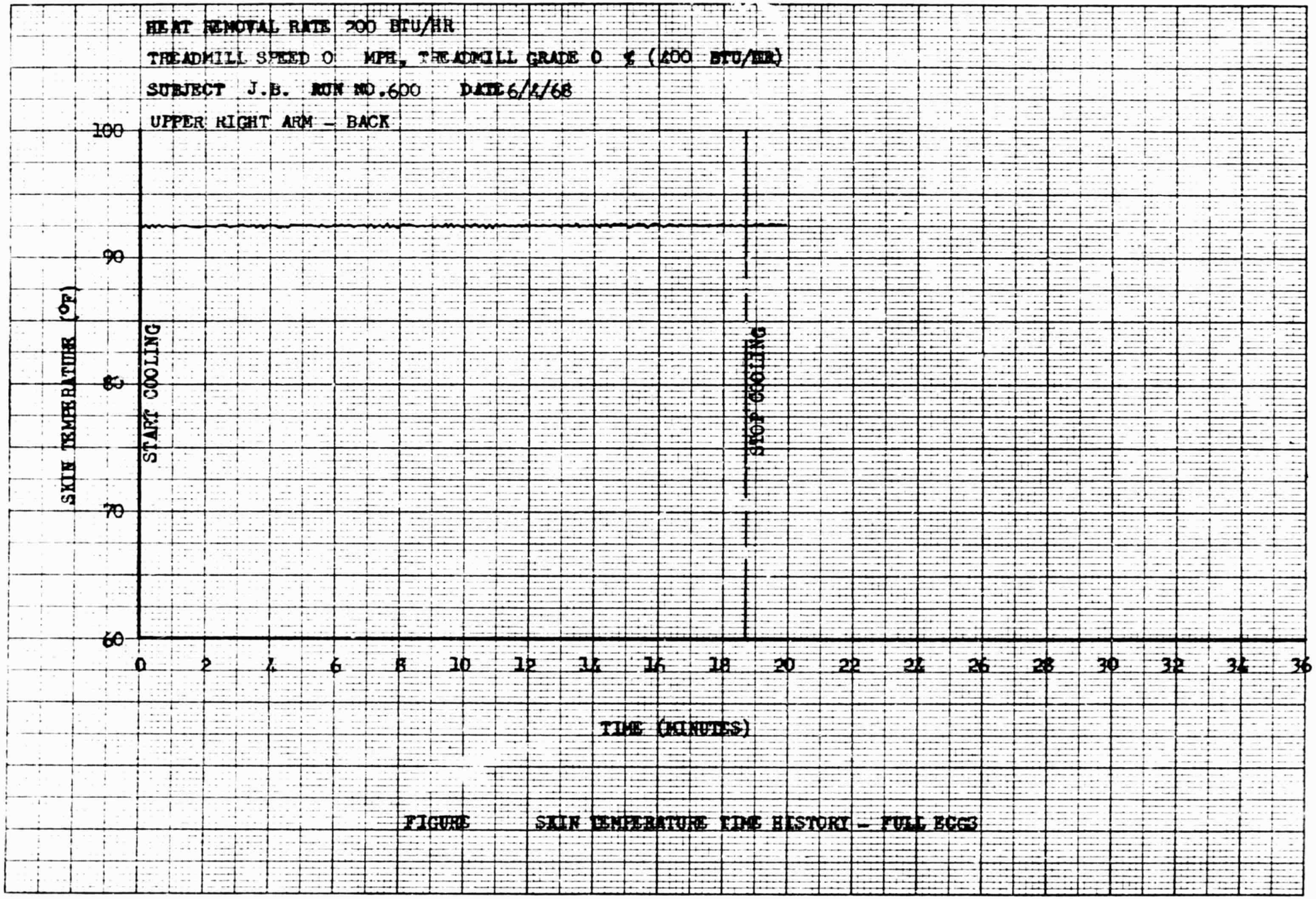


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL EGG3

FIGURE SKIN TEMPERATURE TIME HISTORY - FULL SUIT

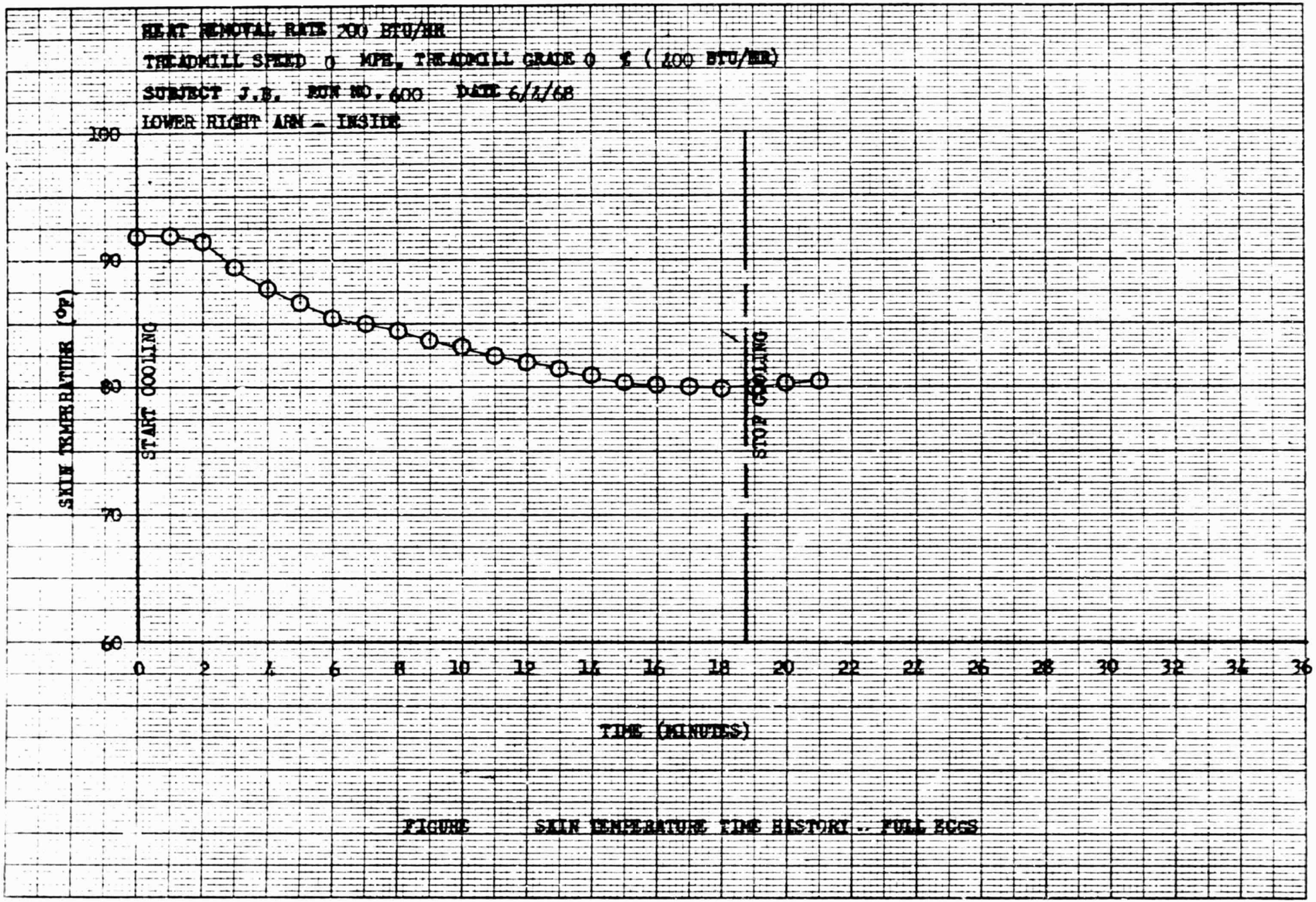


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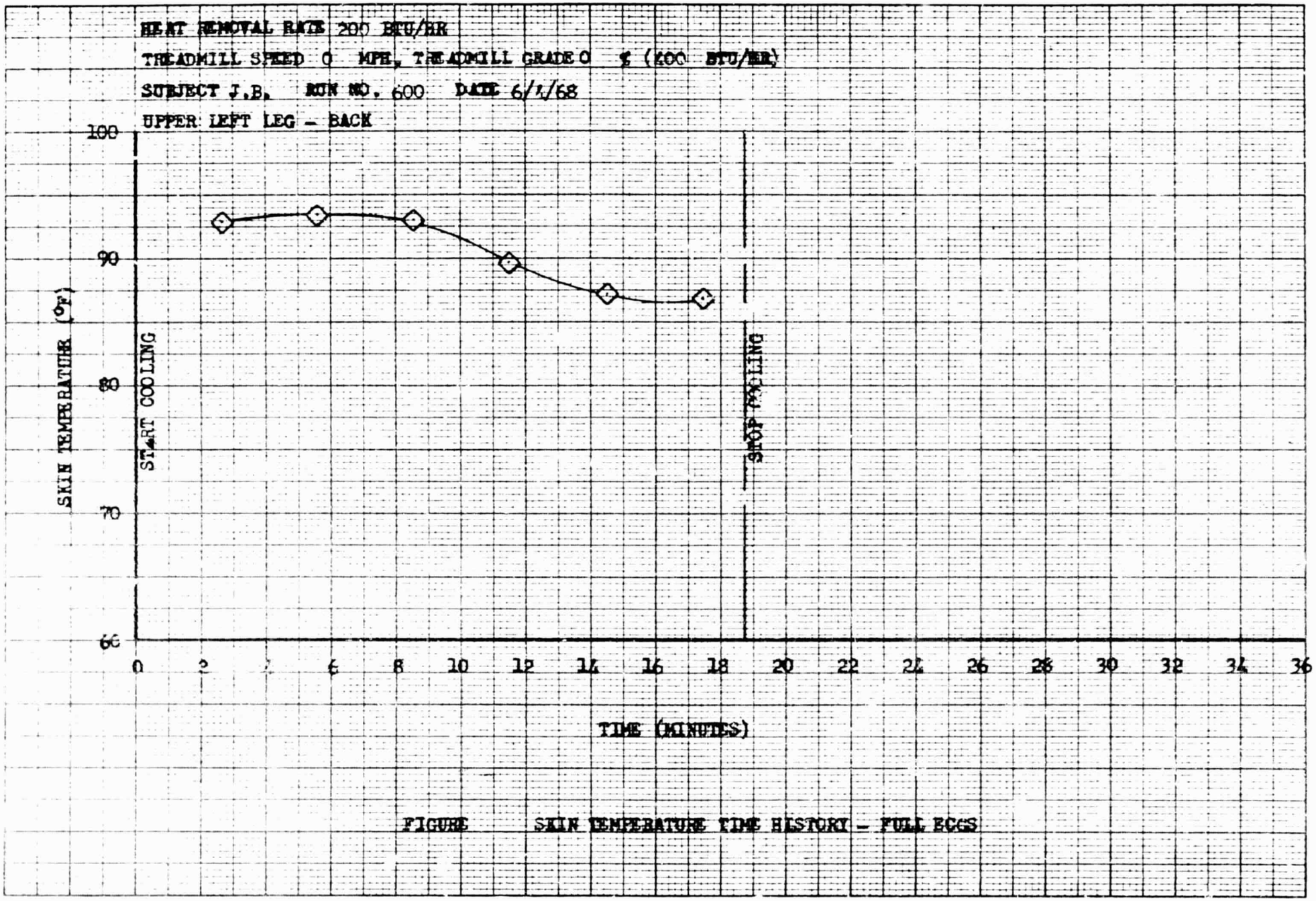


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL EGGS

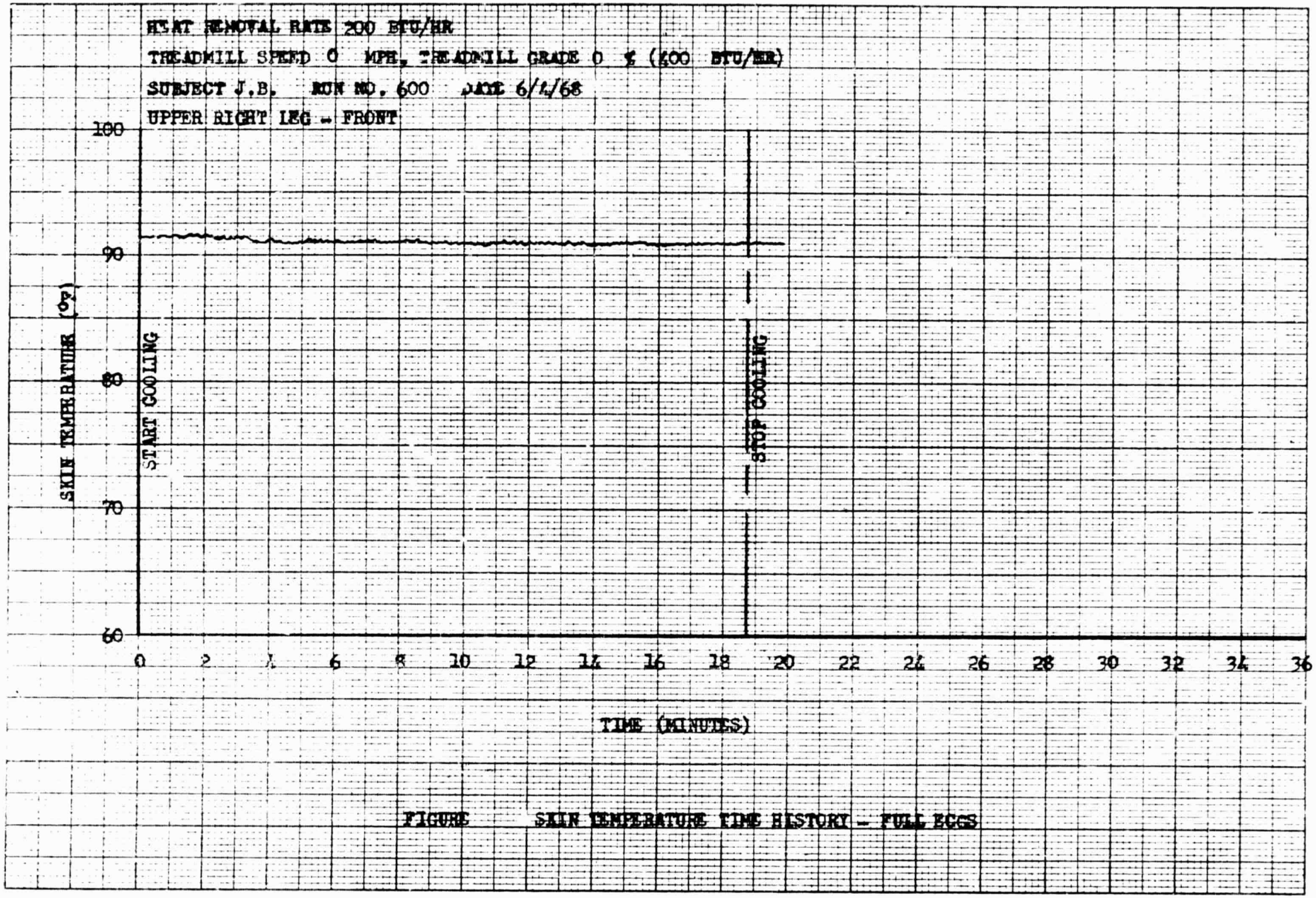


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL EGGS

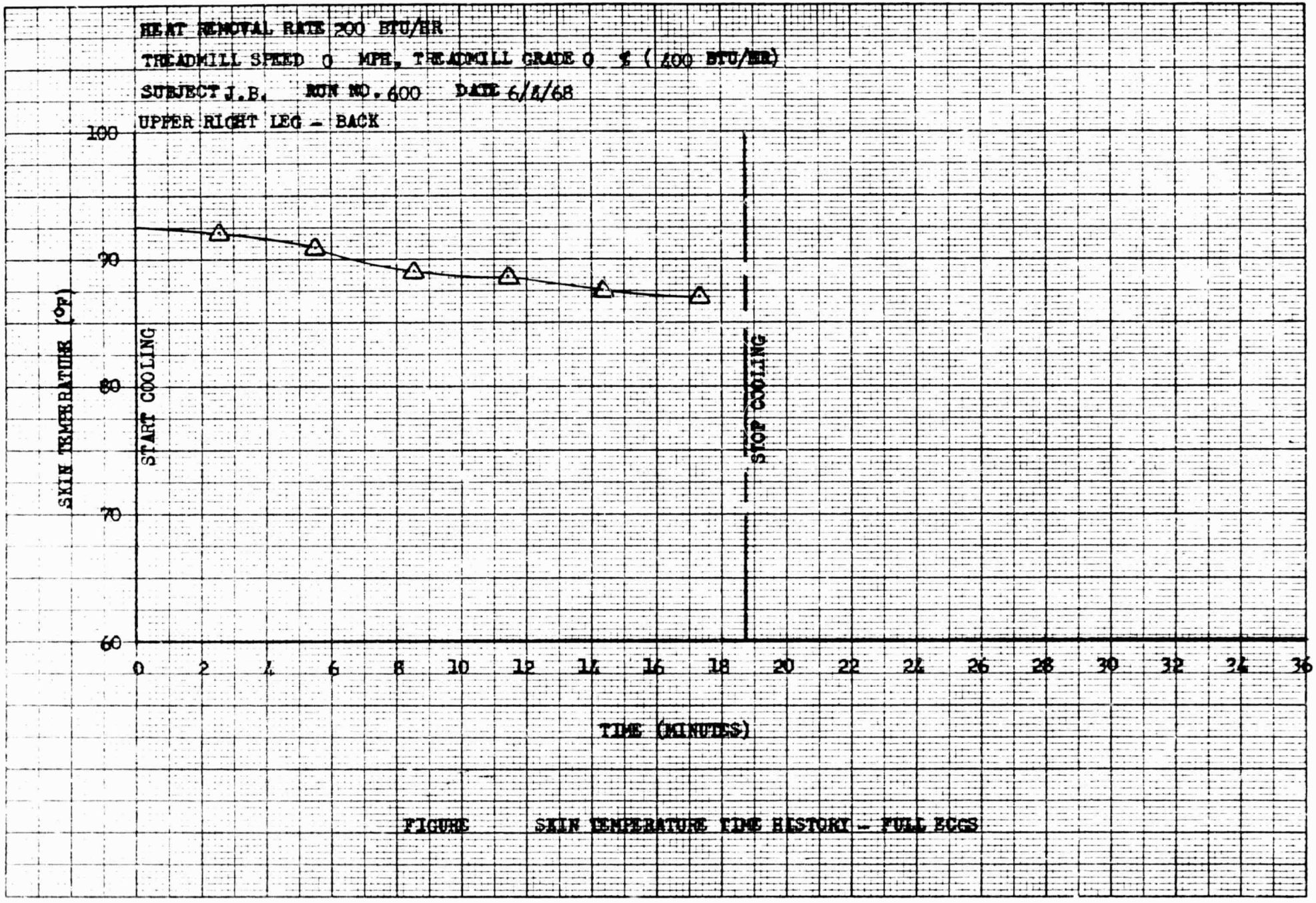


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

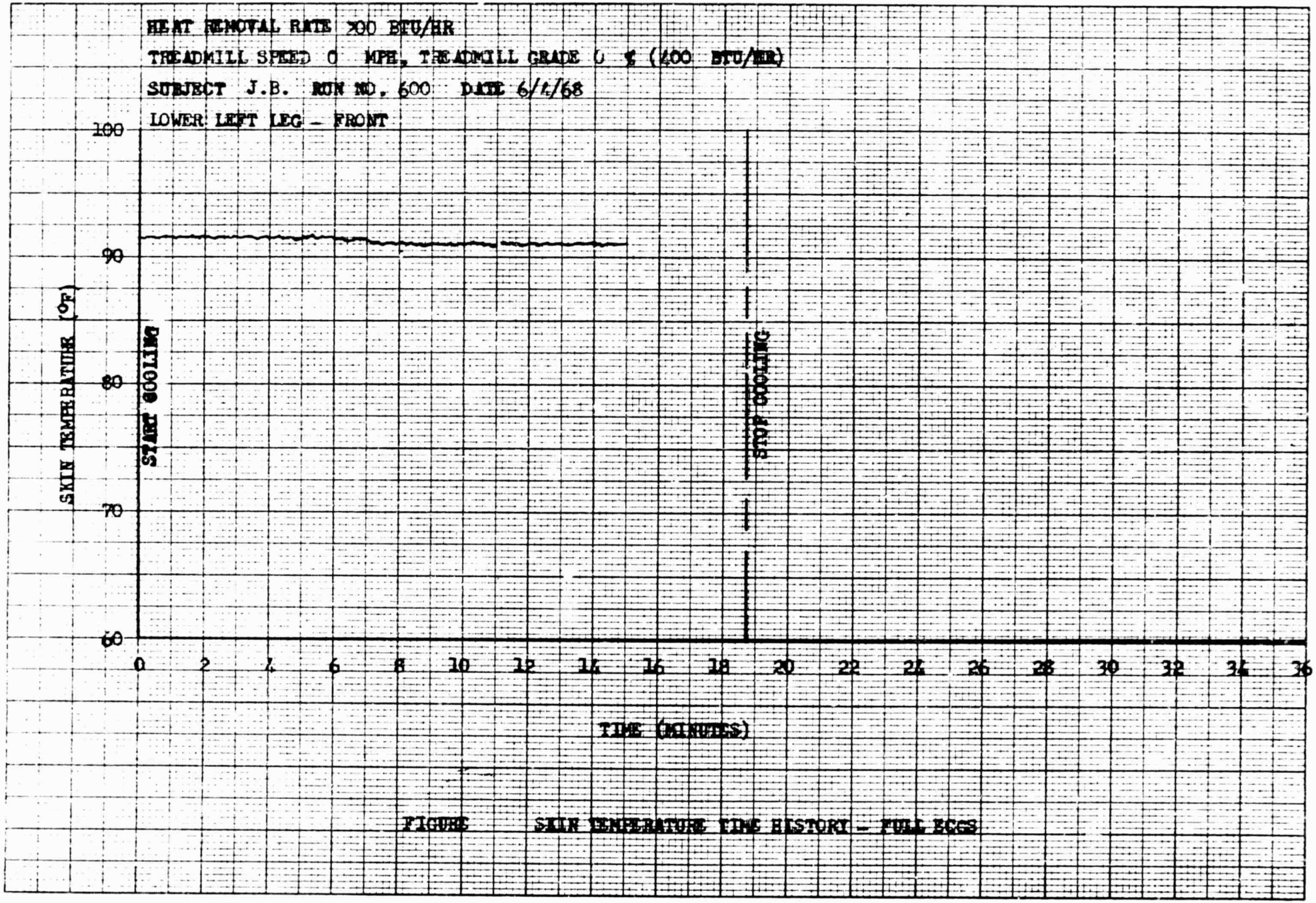


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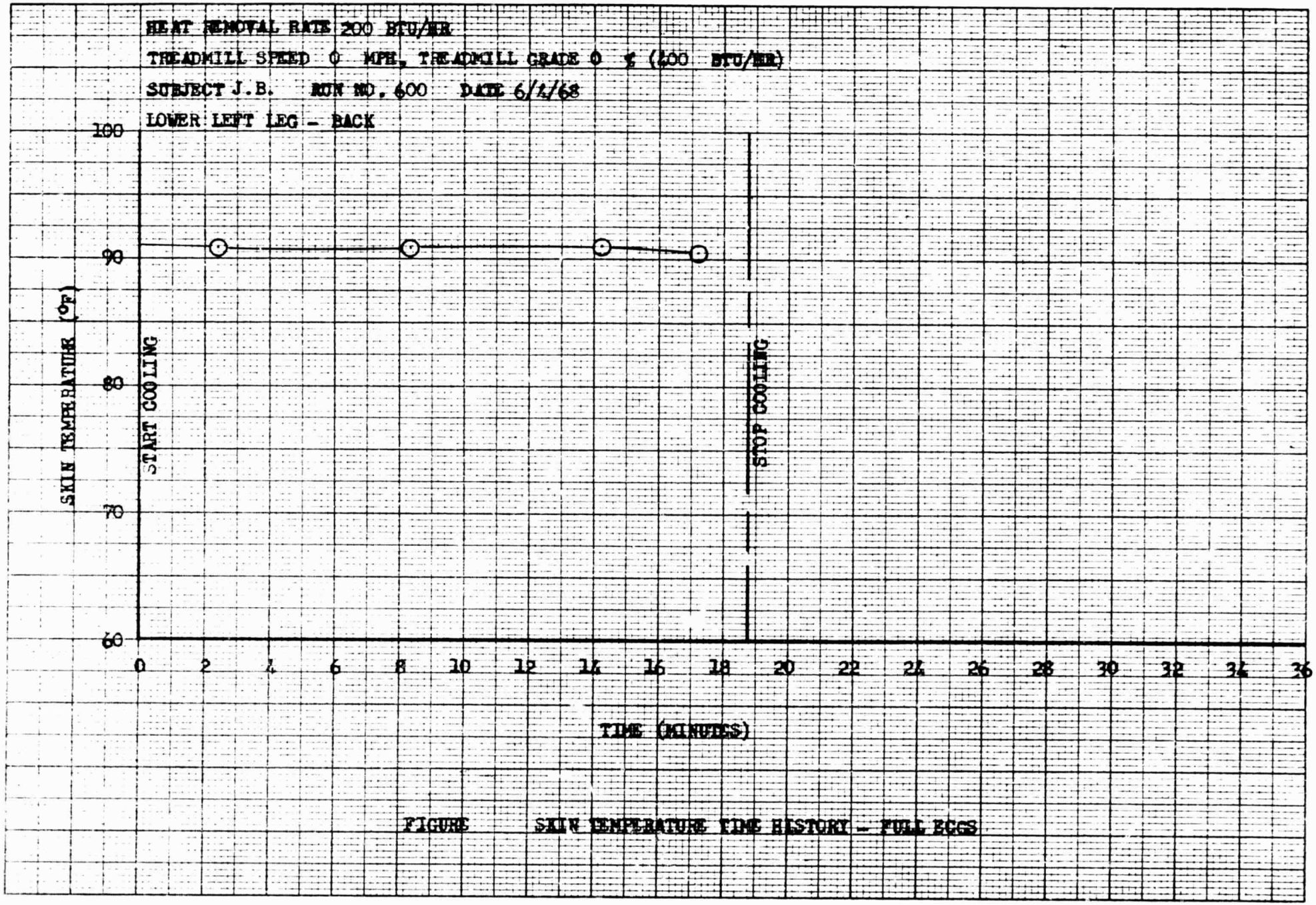


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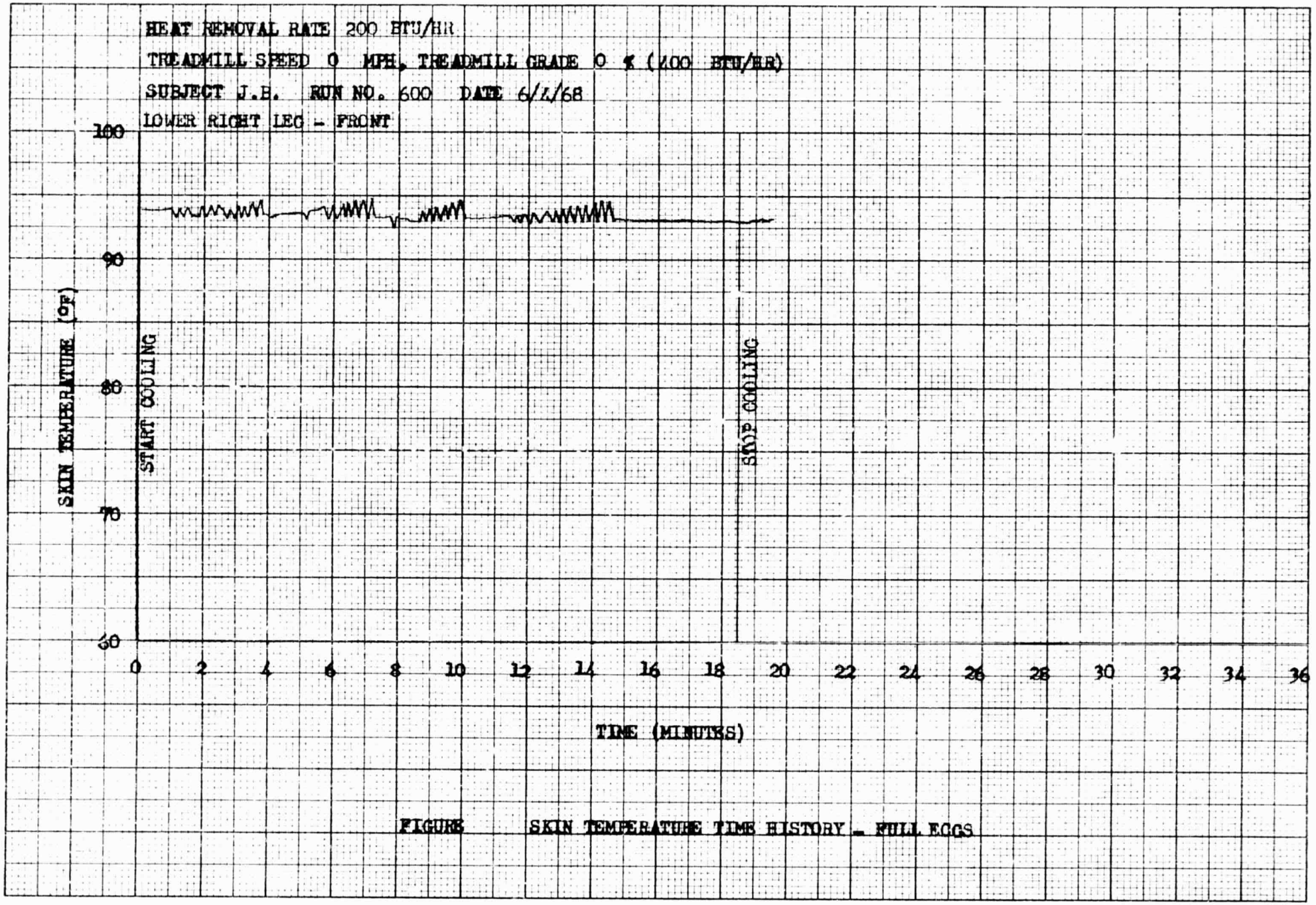


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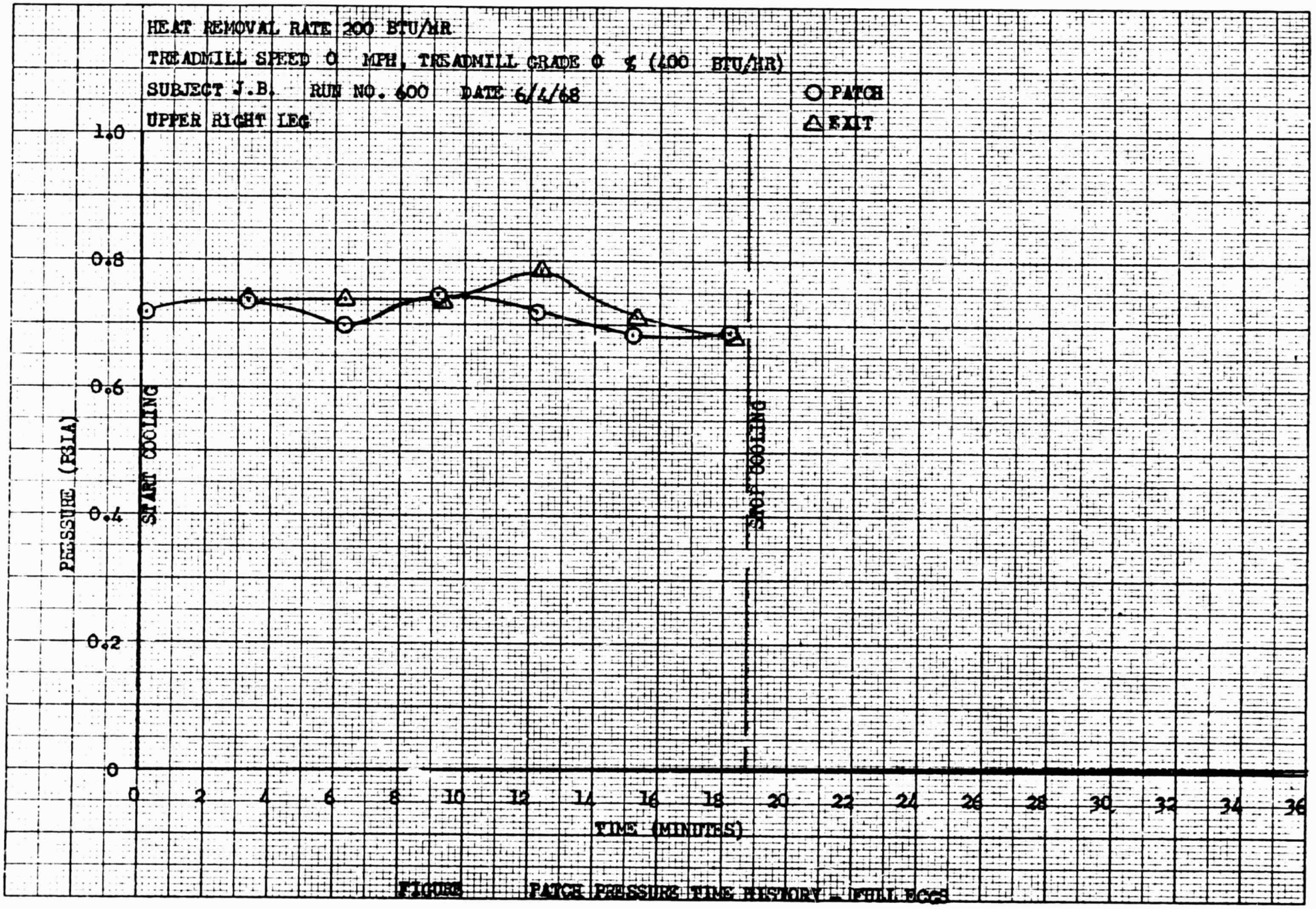


FIGURE PATCH PRESSURE TIME HISTORY - FULL LEGS

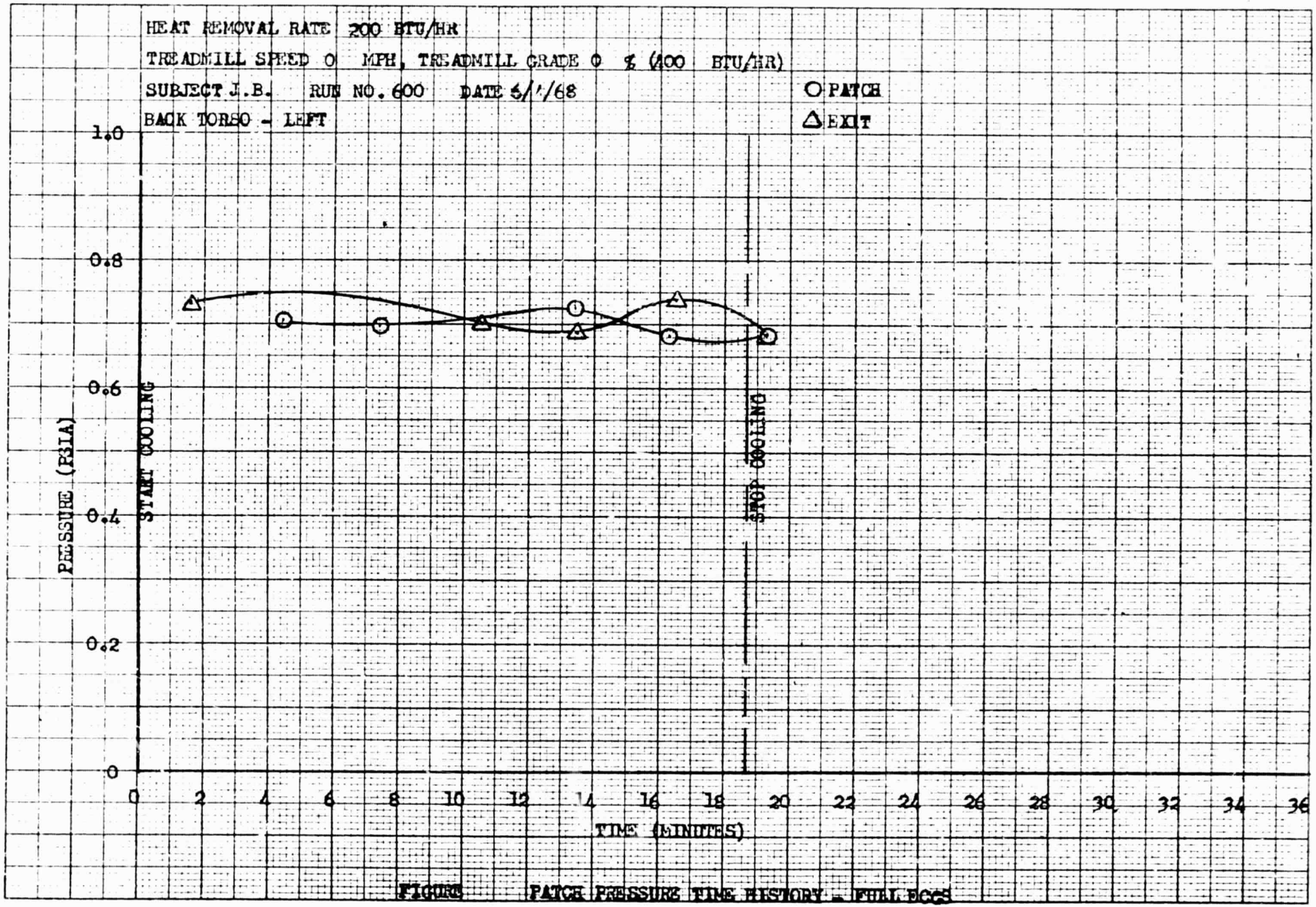


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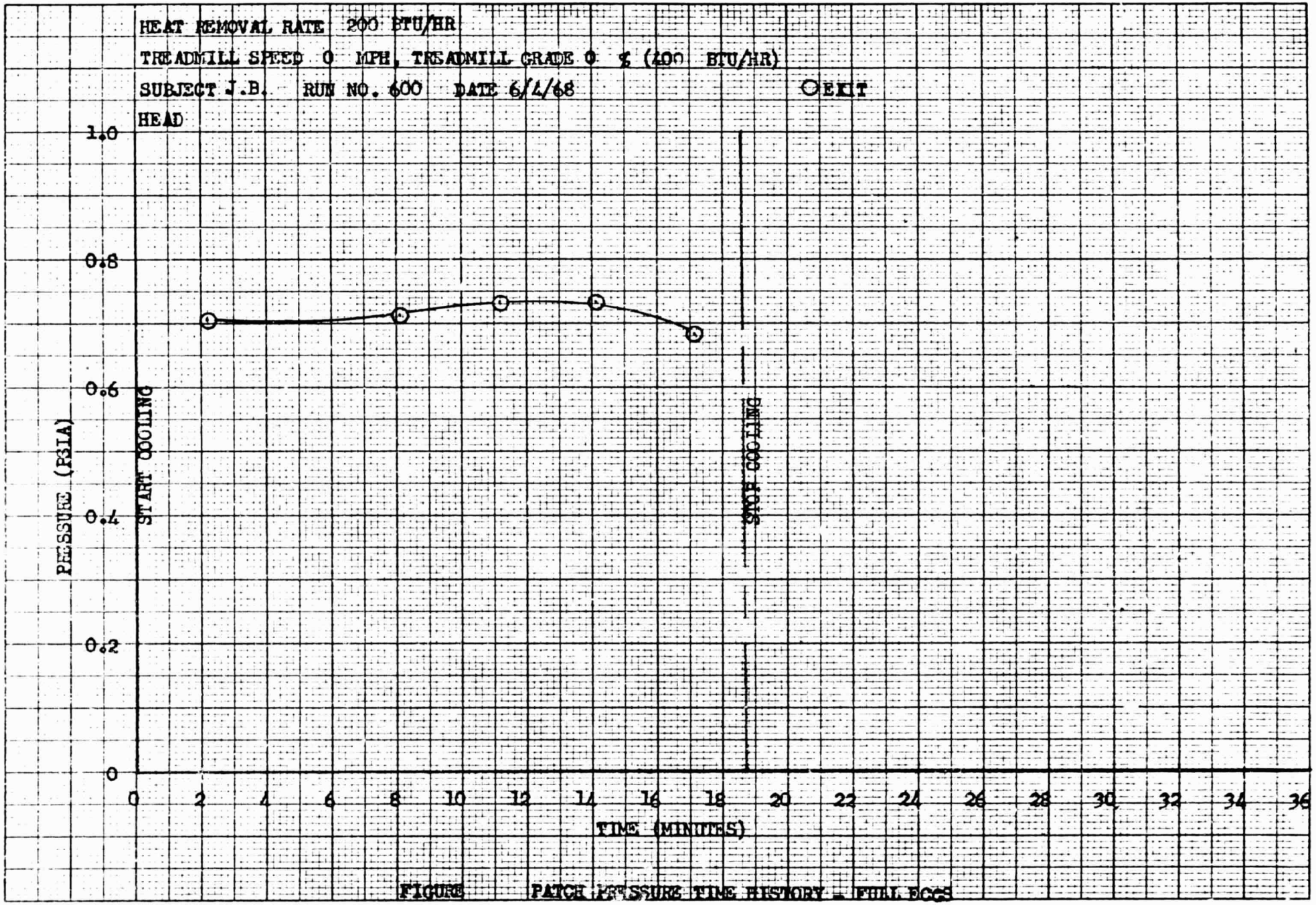


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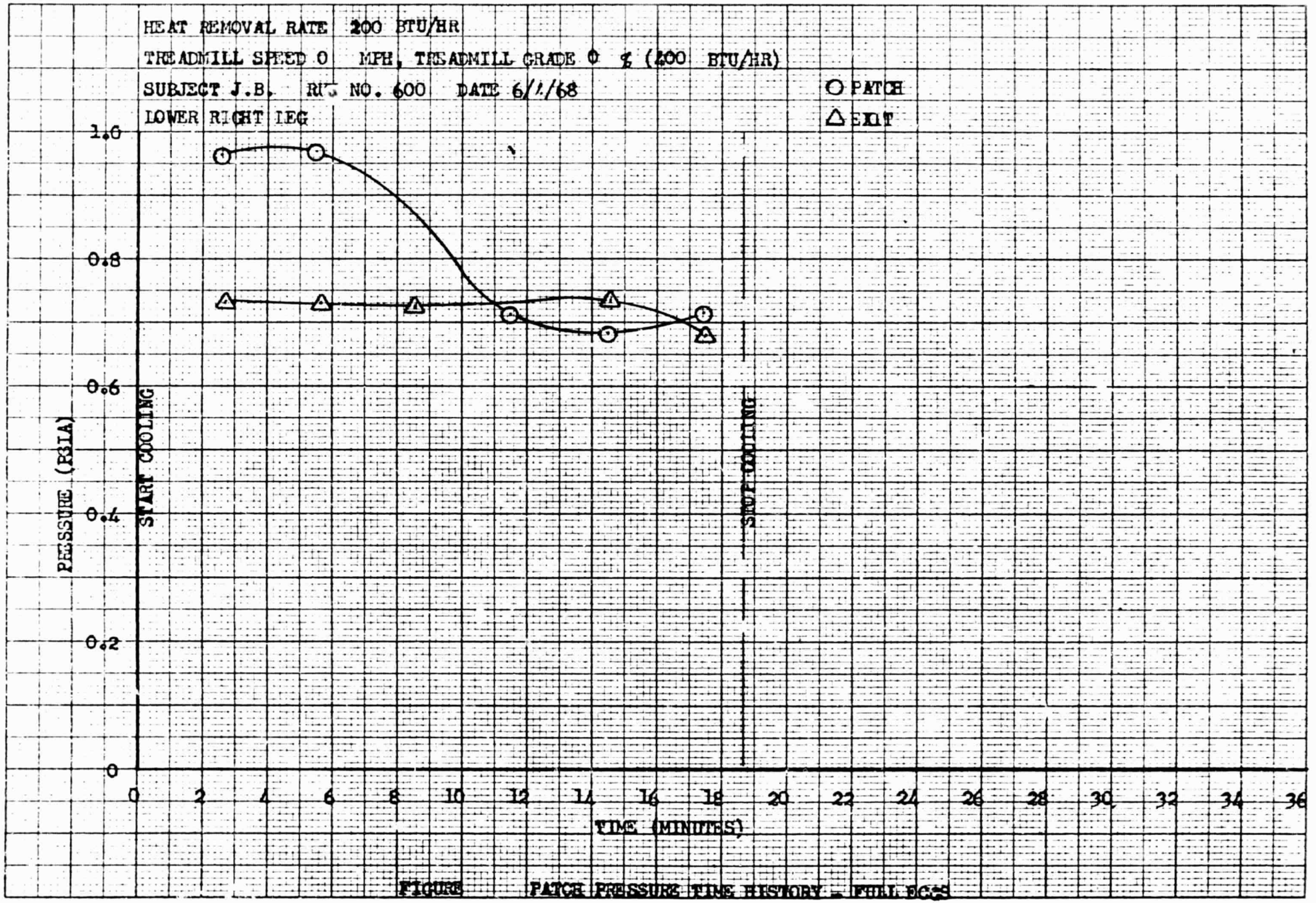


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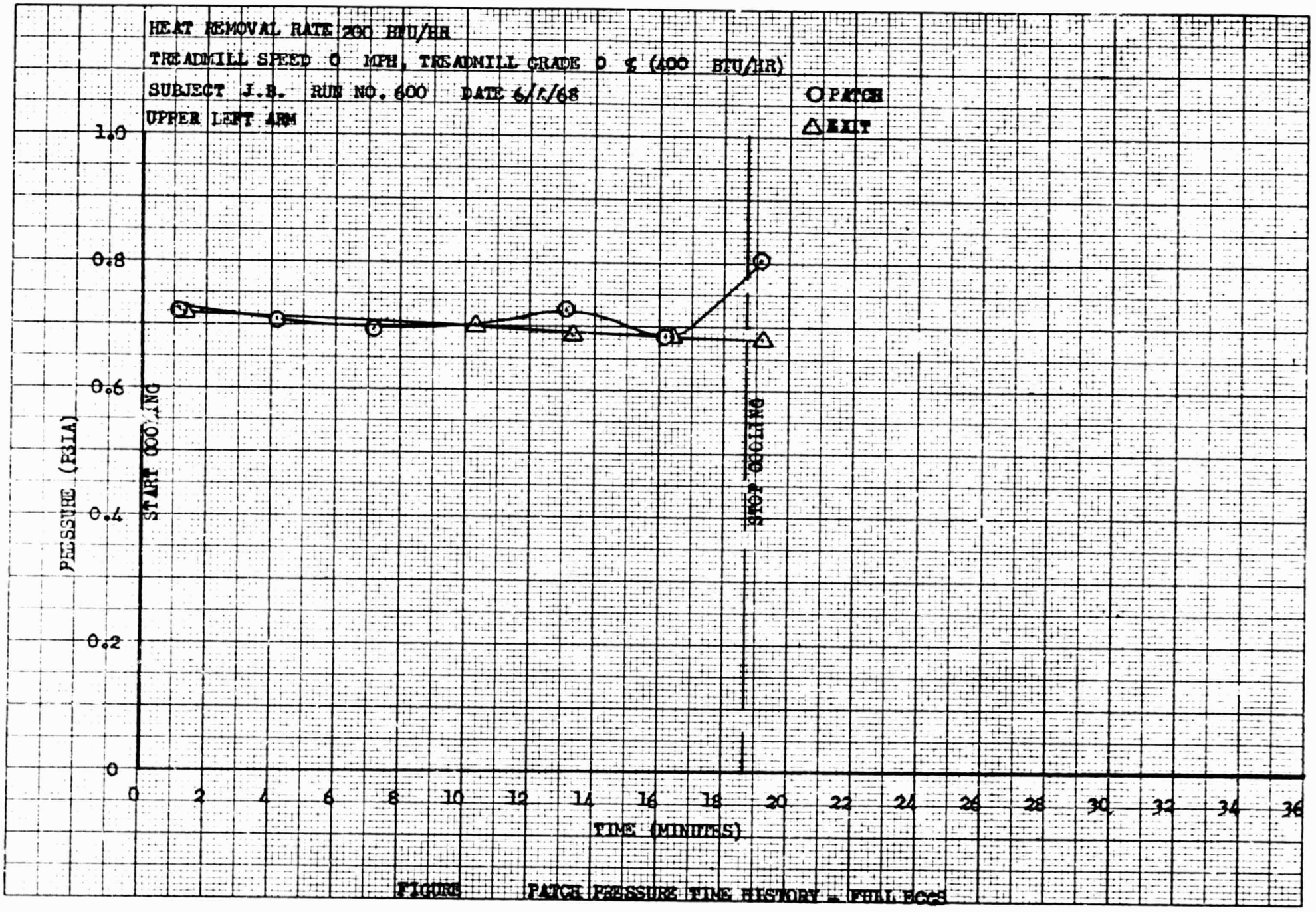


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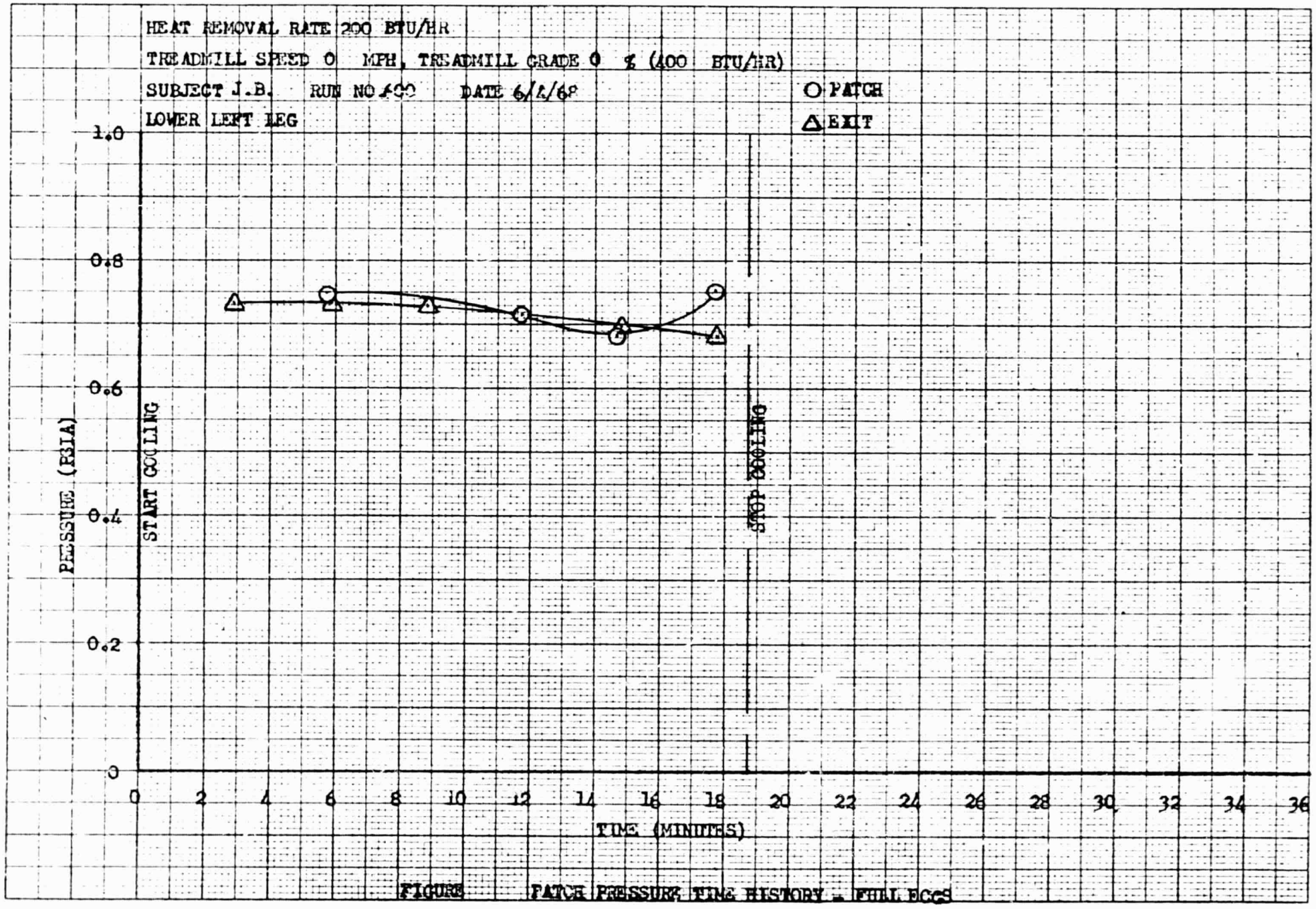


FIGURE PATCH PRESSURE TIME HISTORY - FULL ECGS

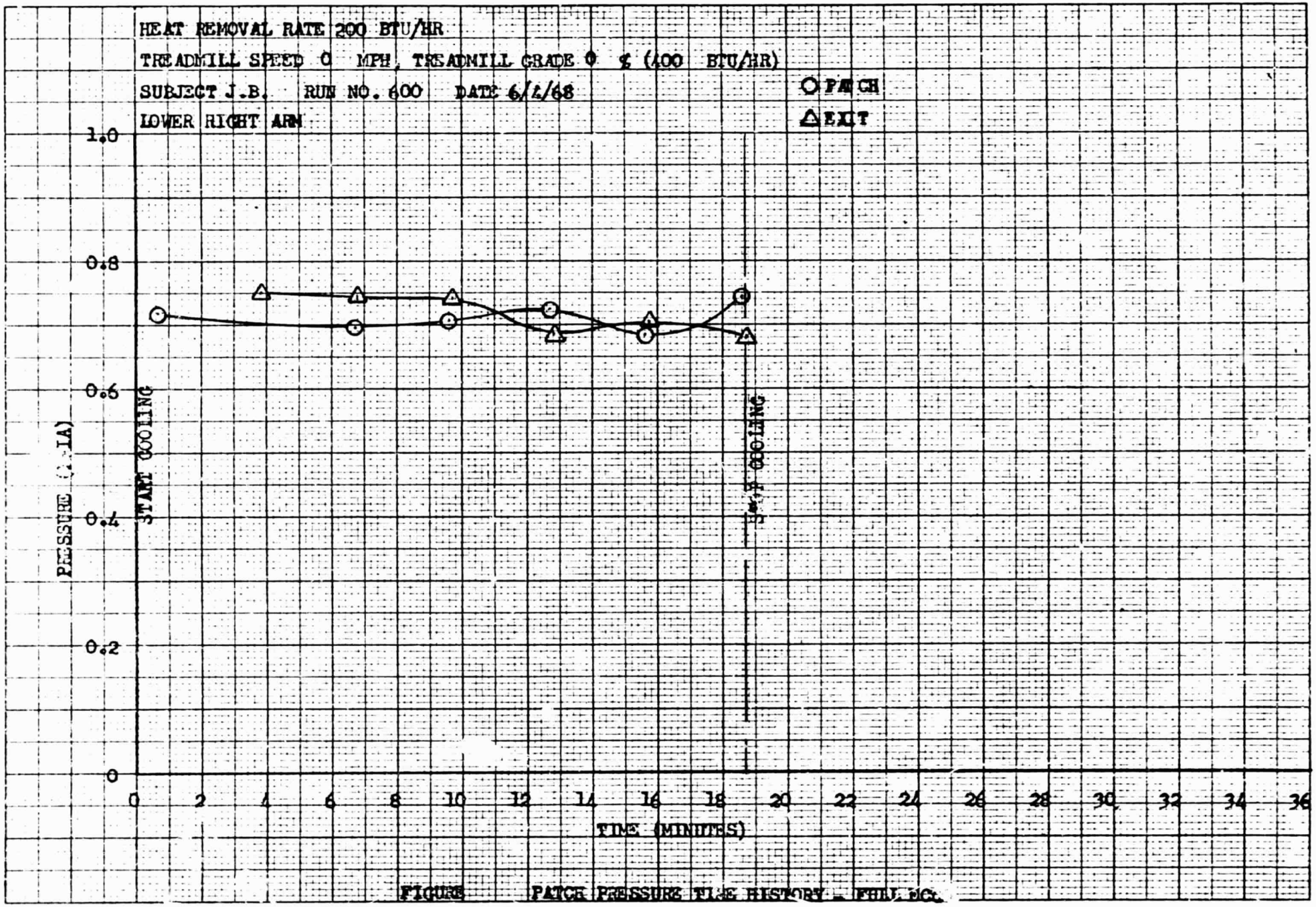


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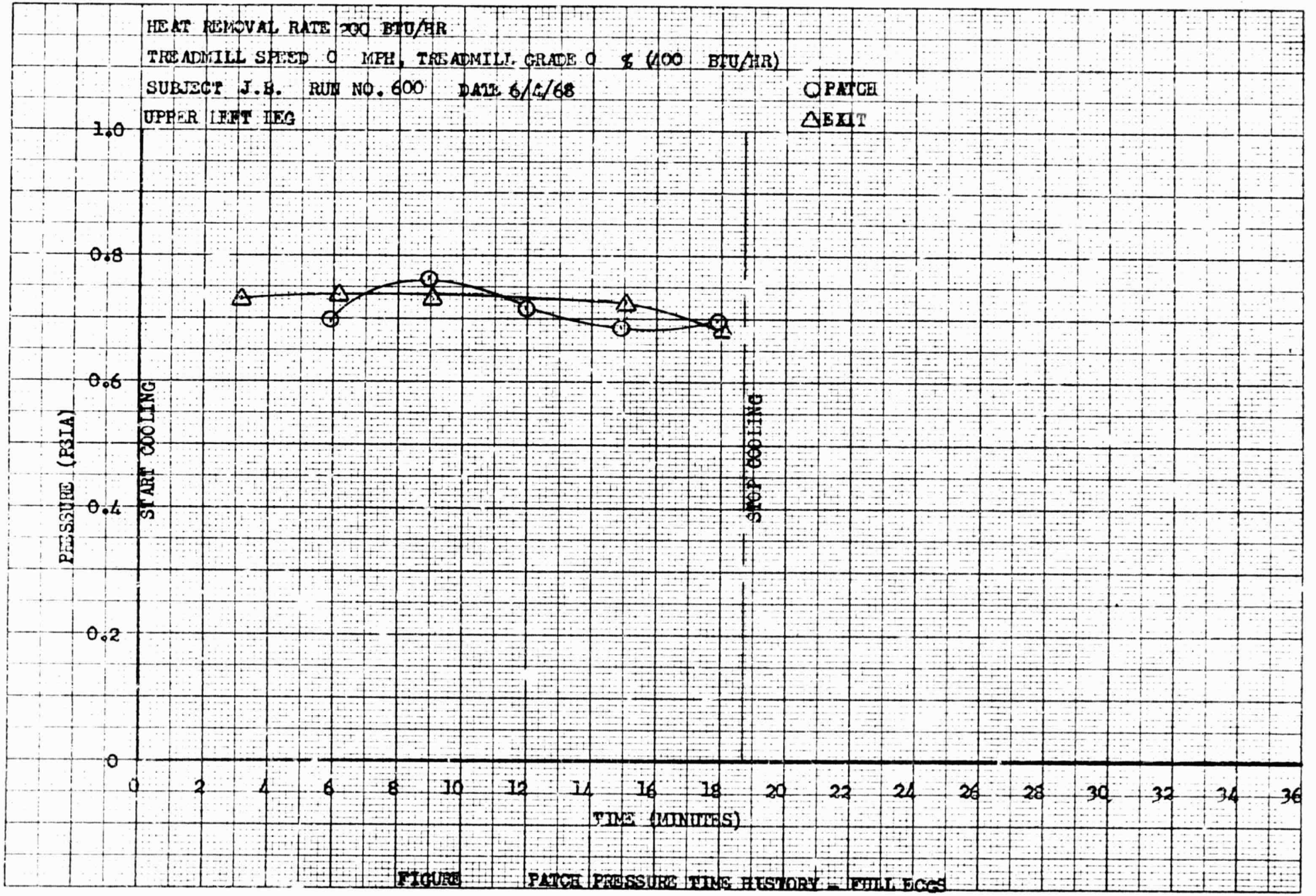


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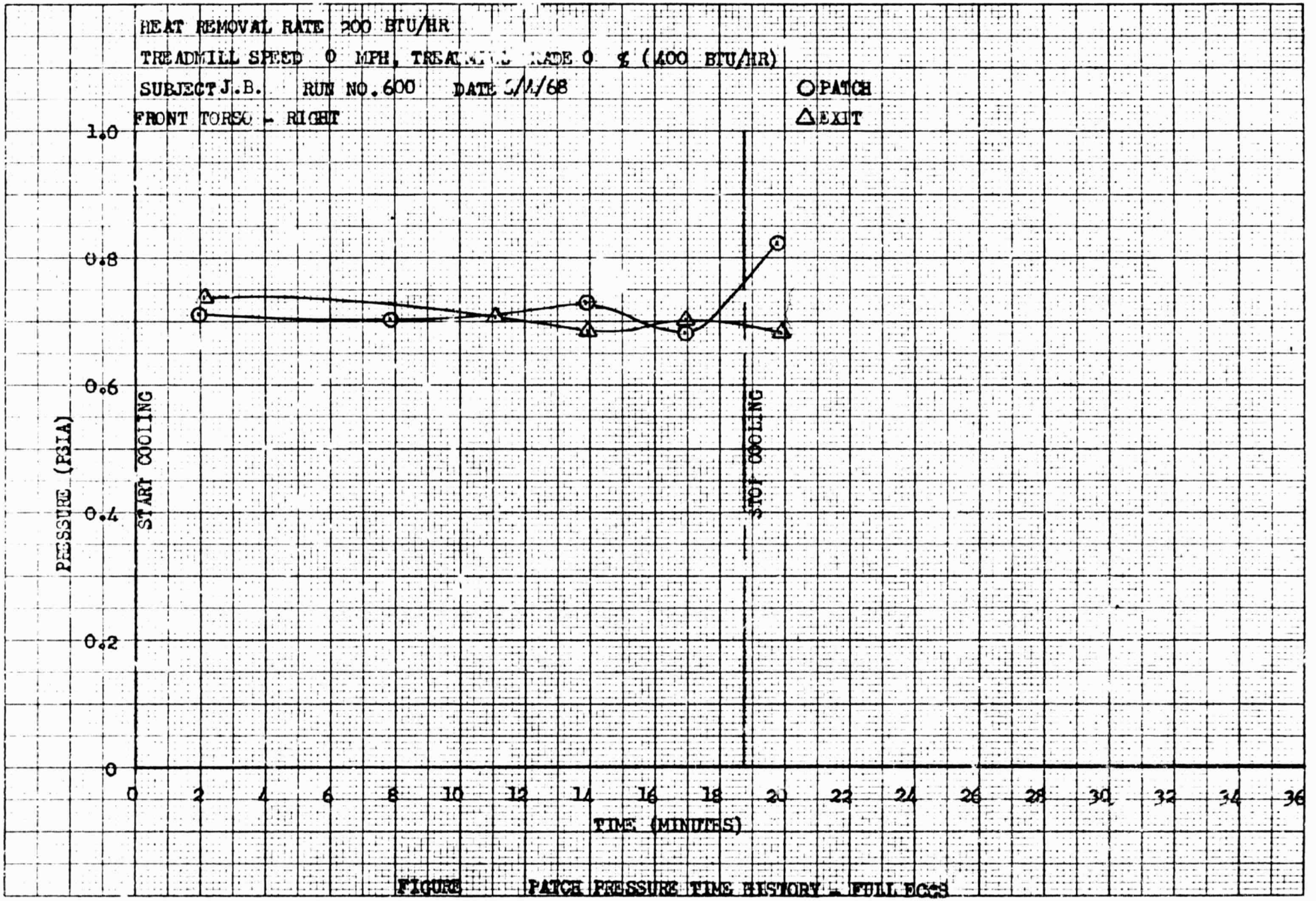


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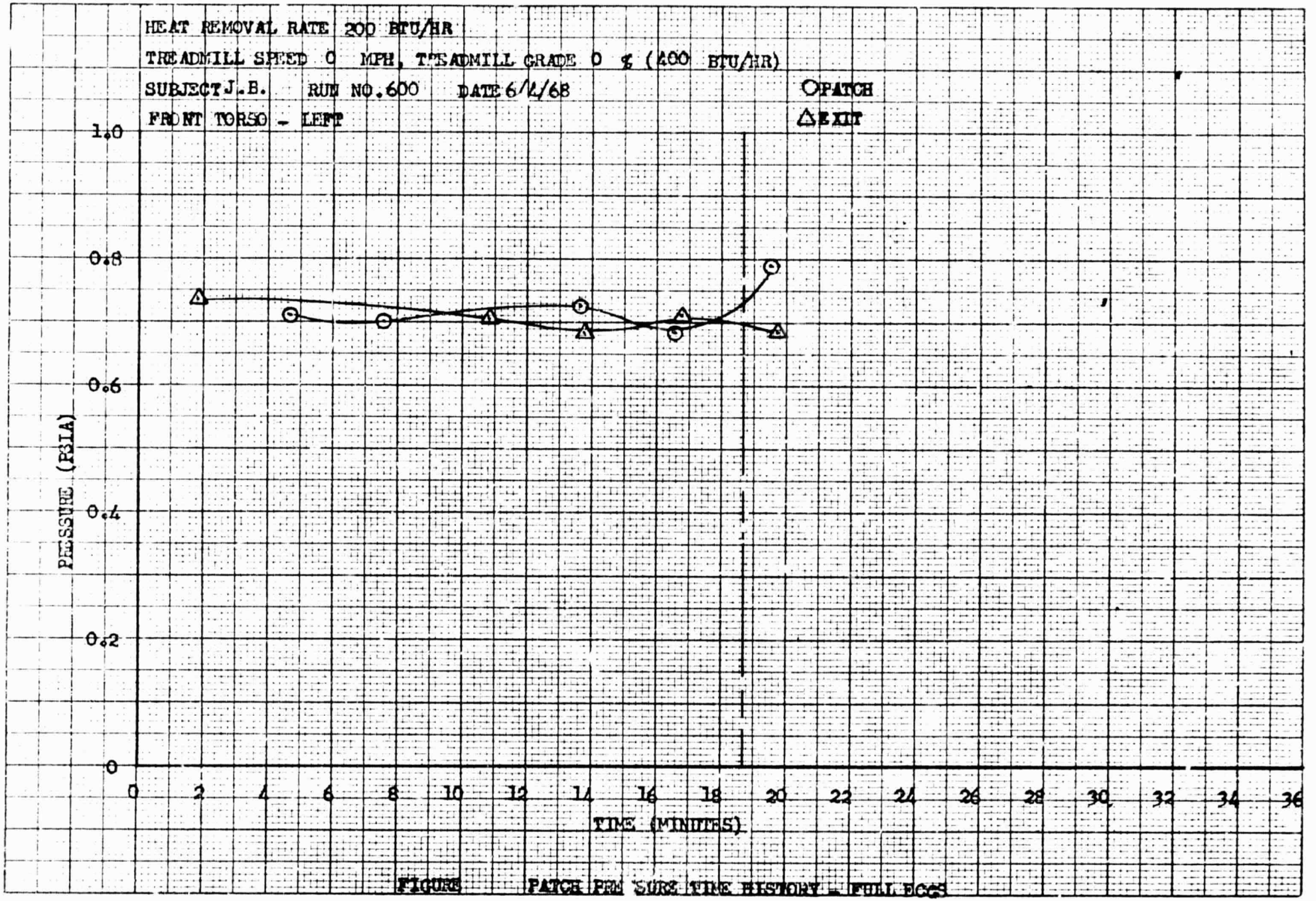


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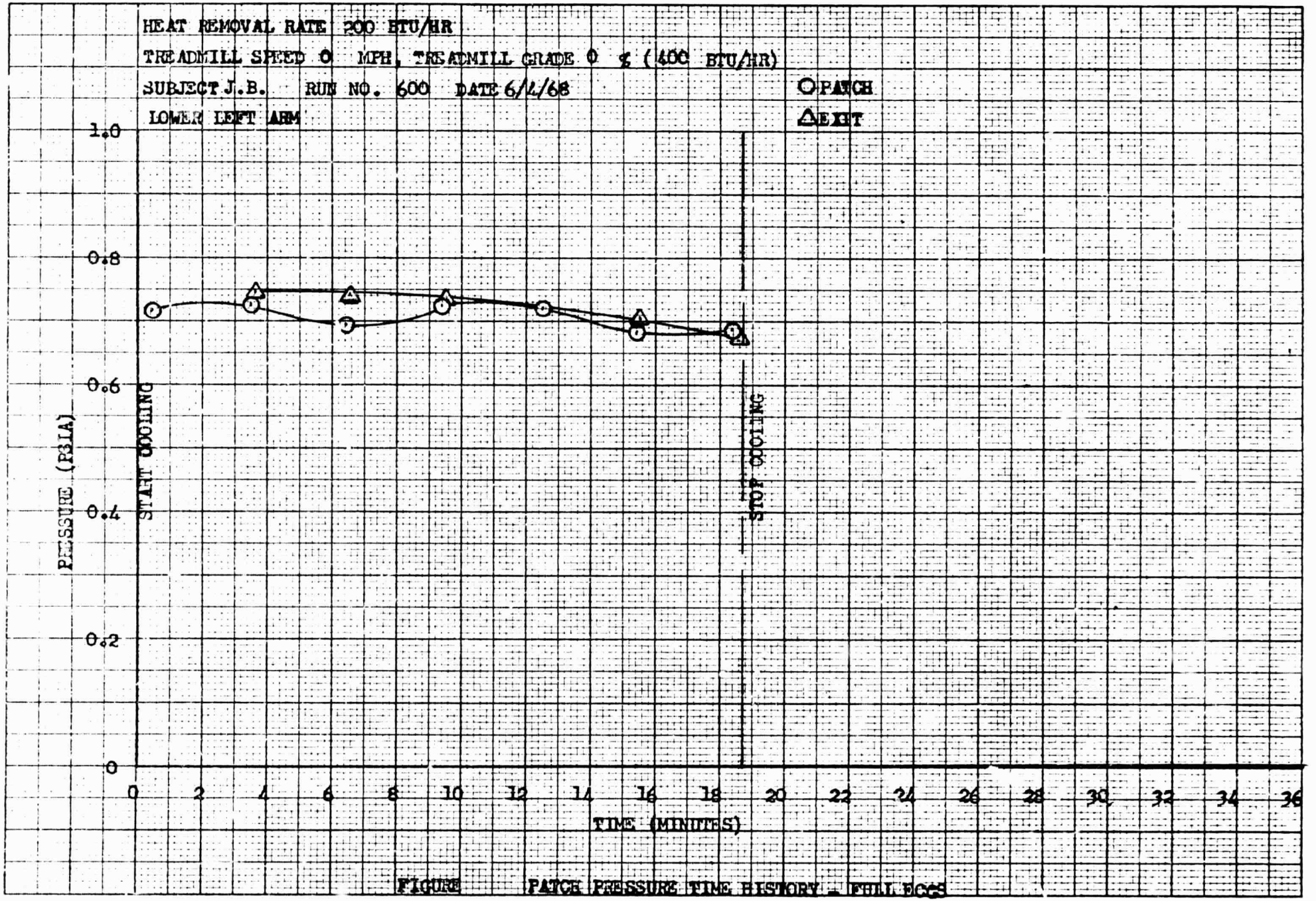


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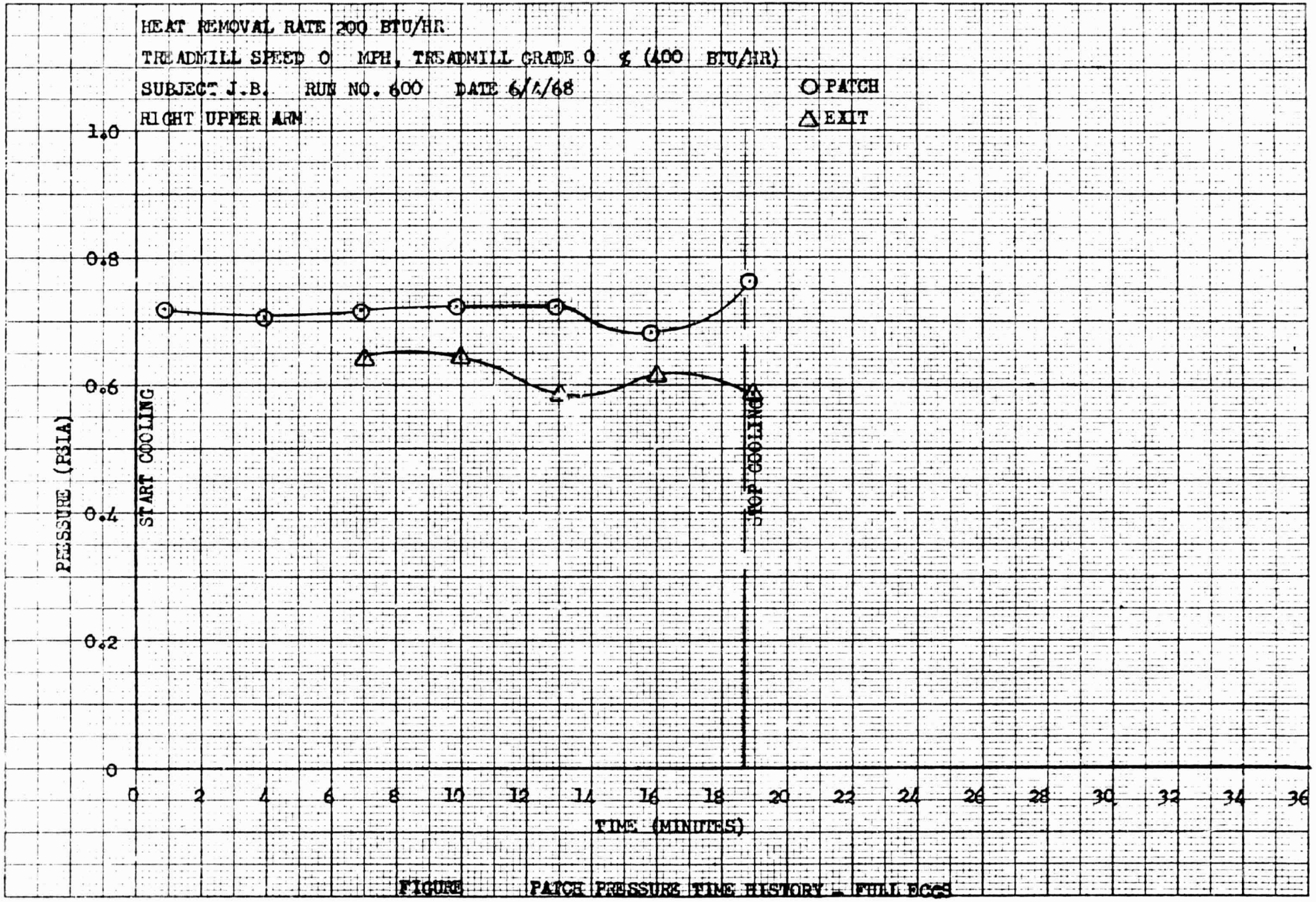


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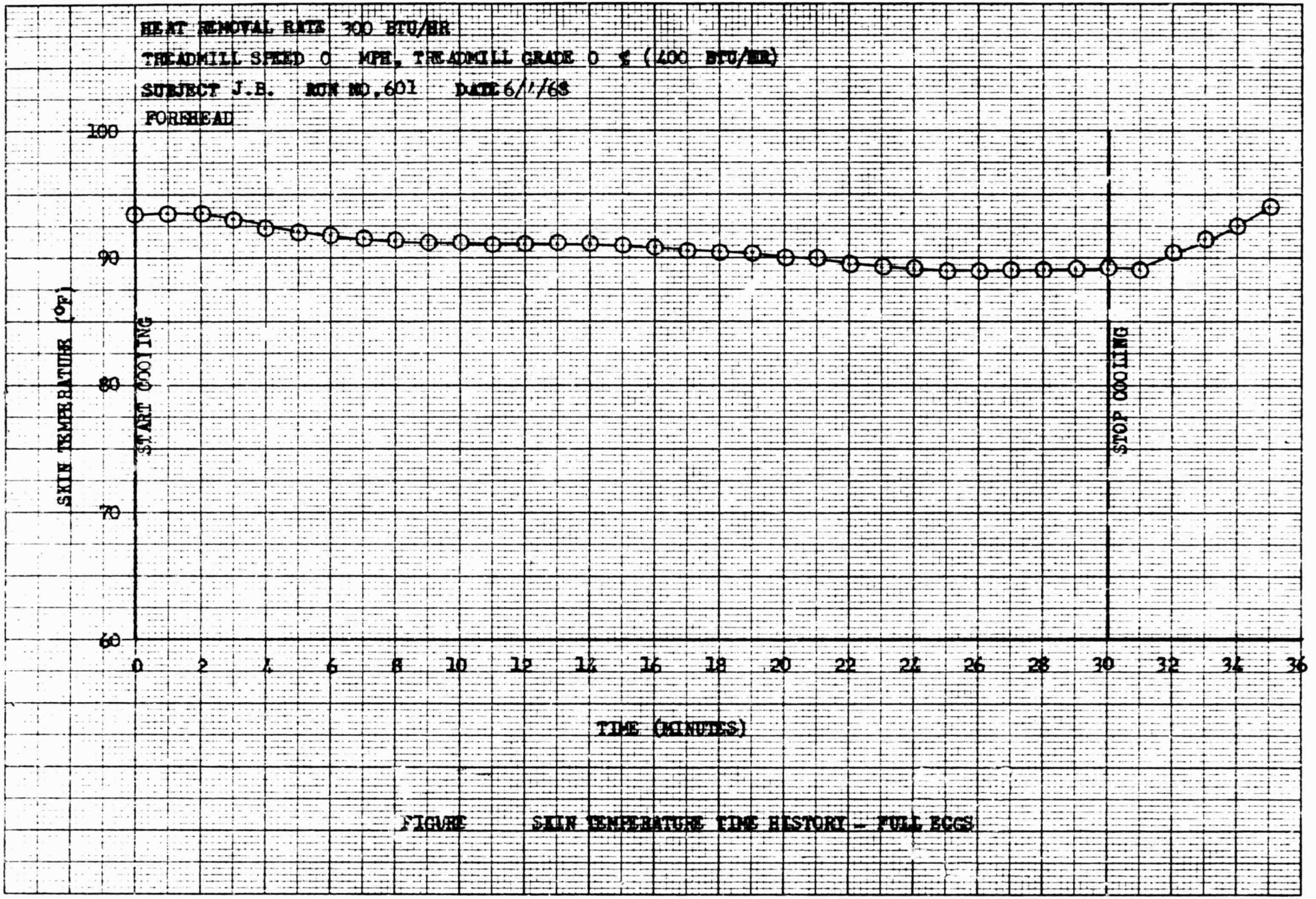


FIGURE SKIN TEMPERATURE TIME HISTORY – FULL ECGS

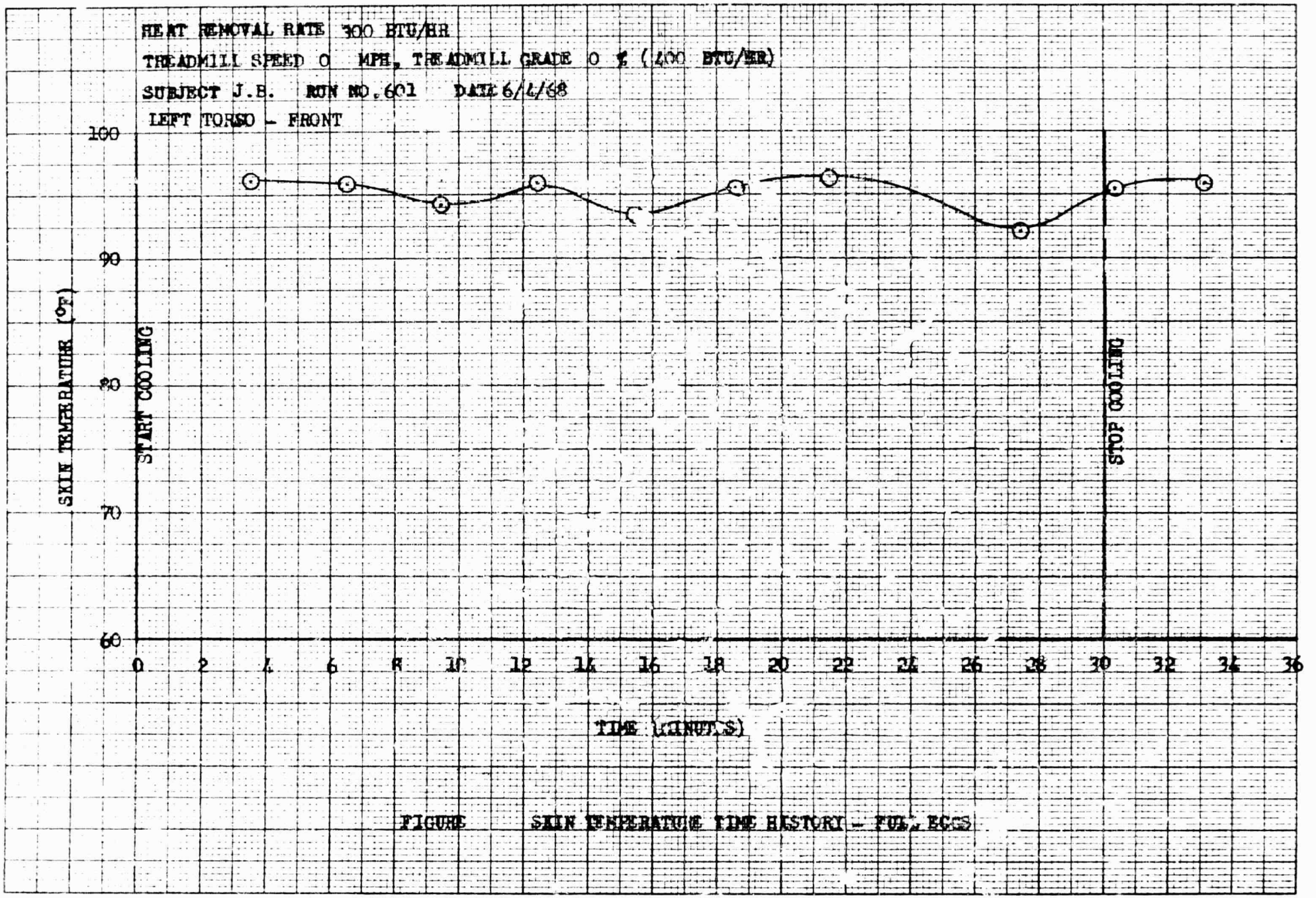


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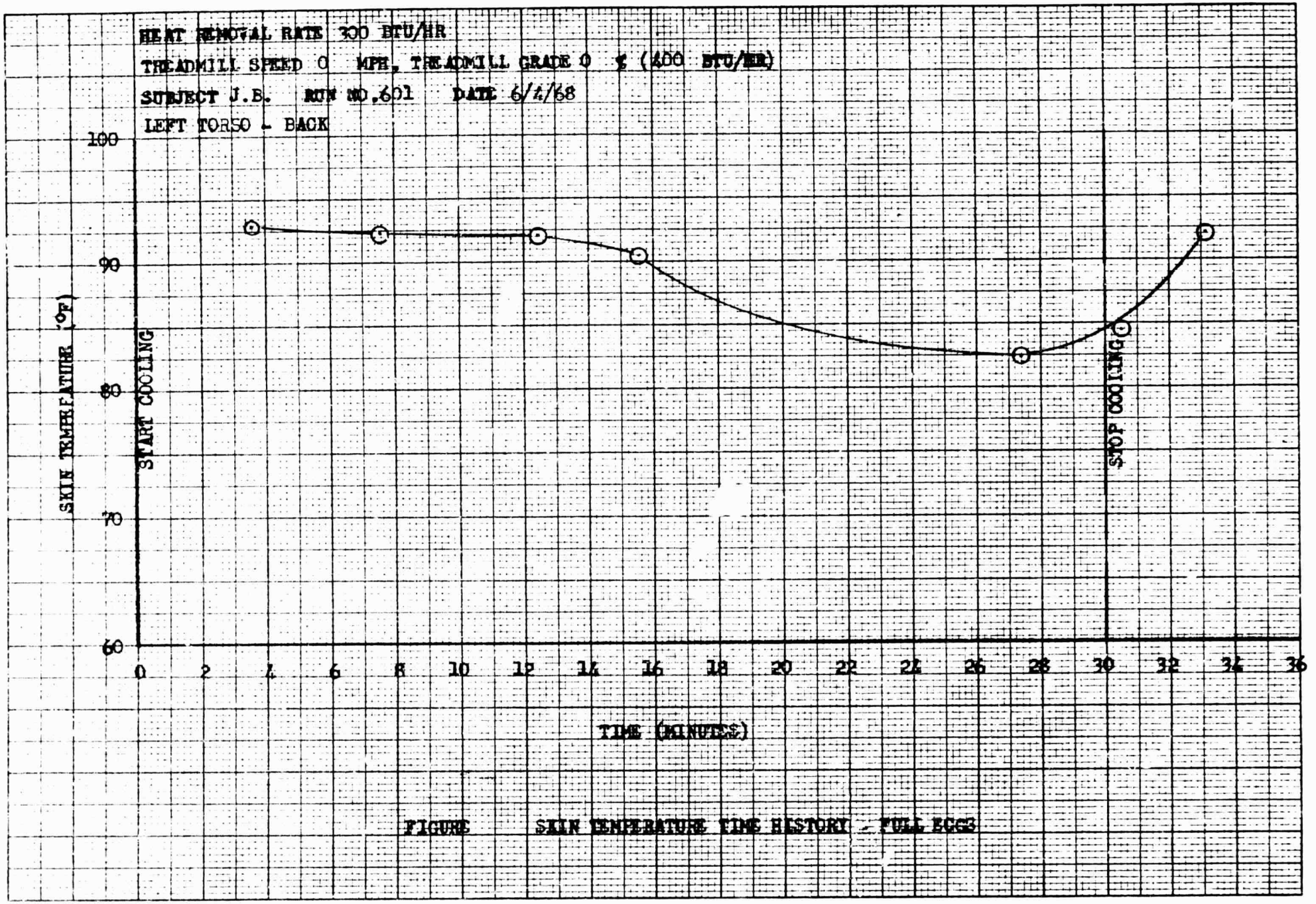


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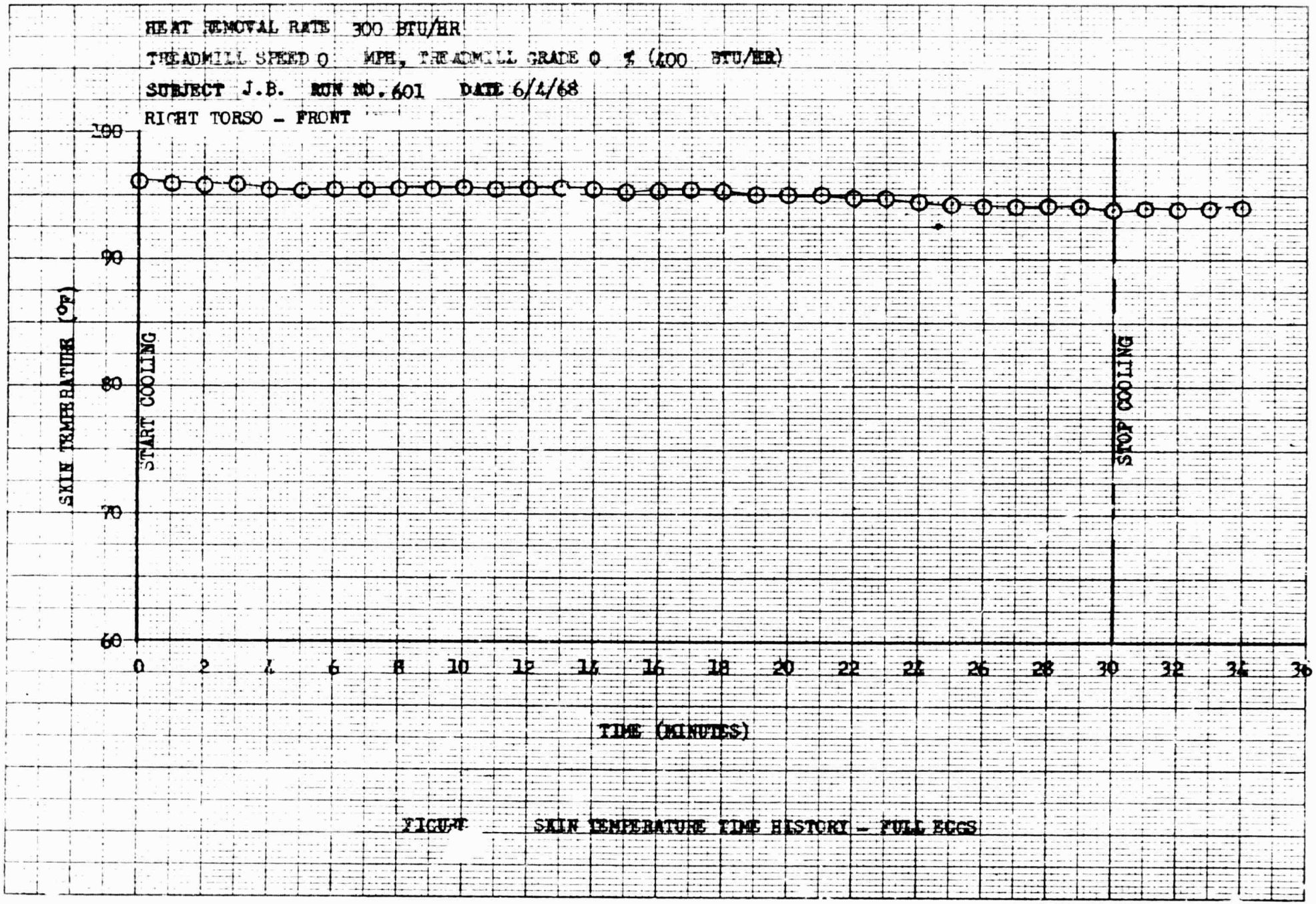


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

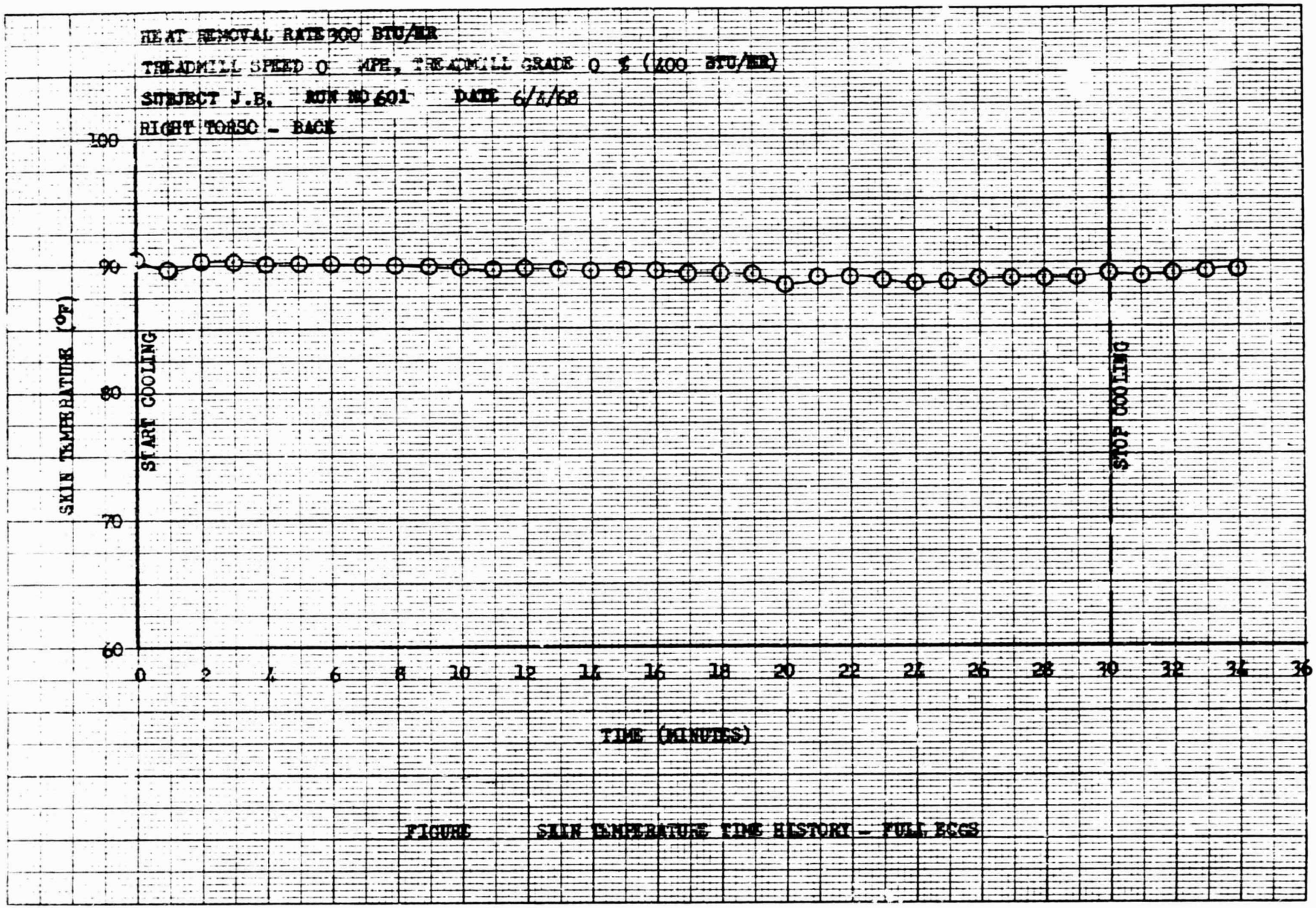


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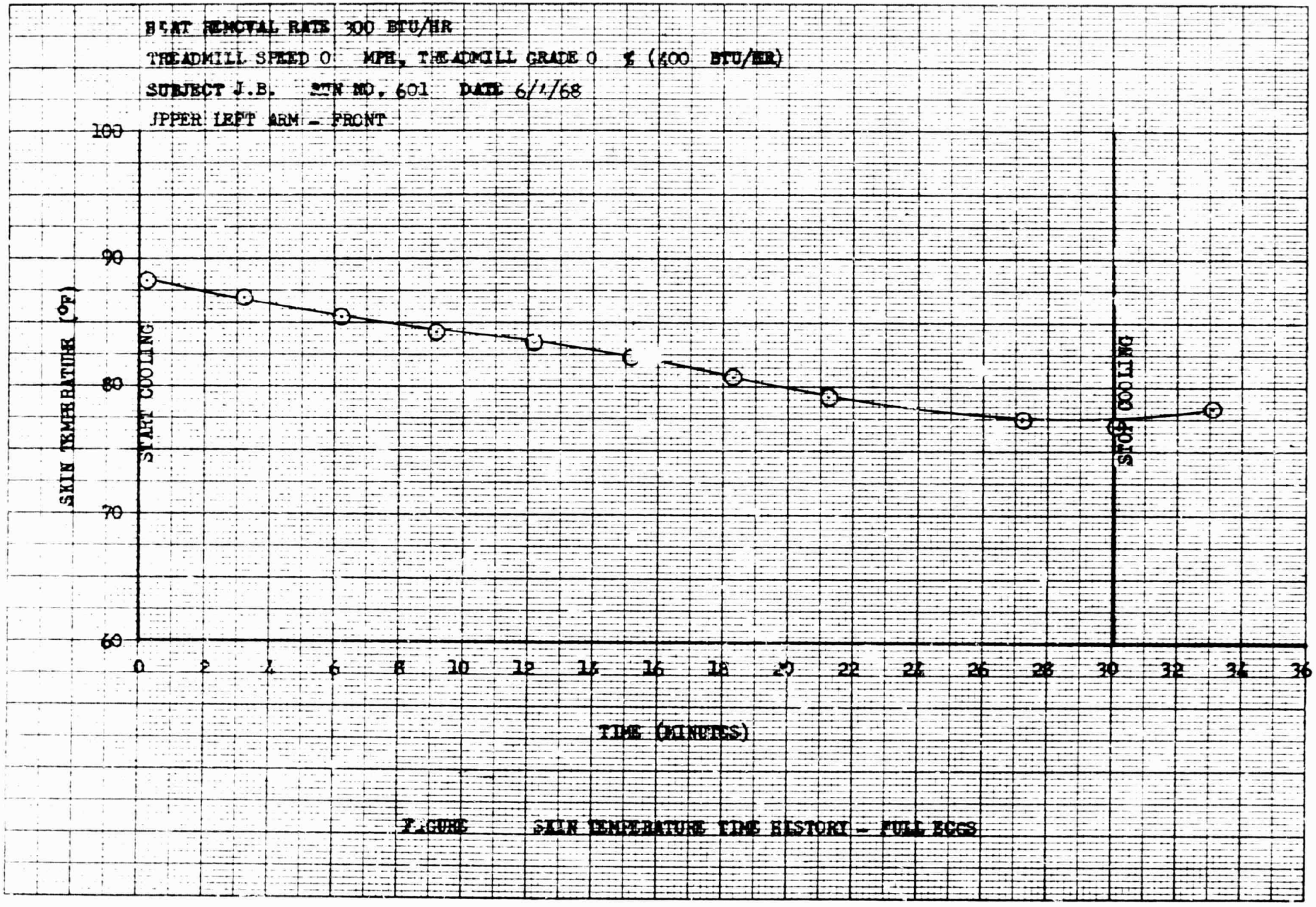


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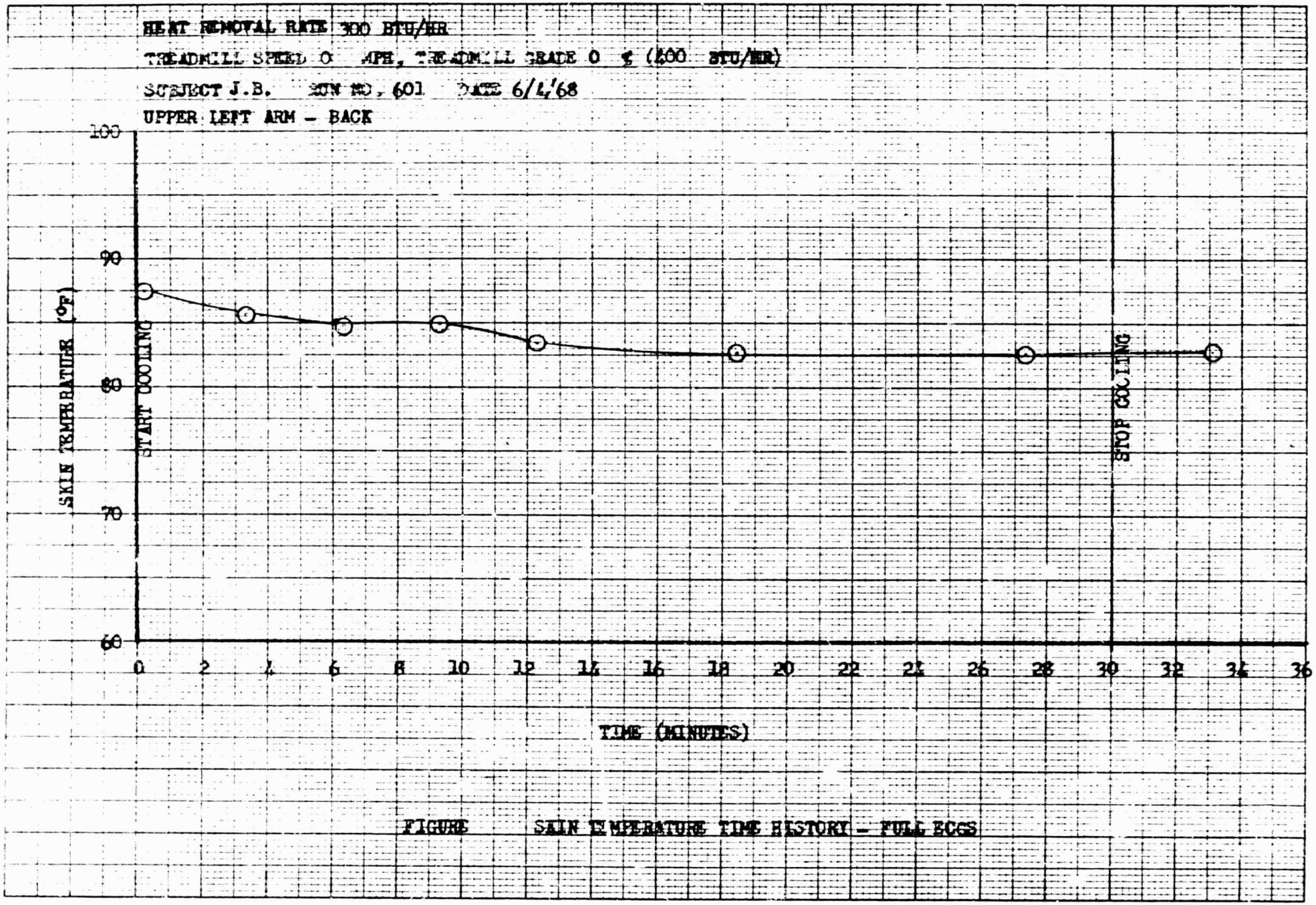


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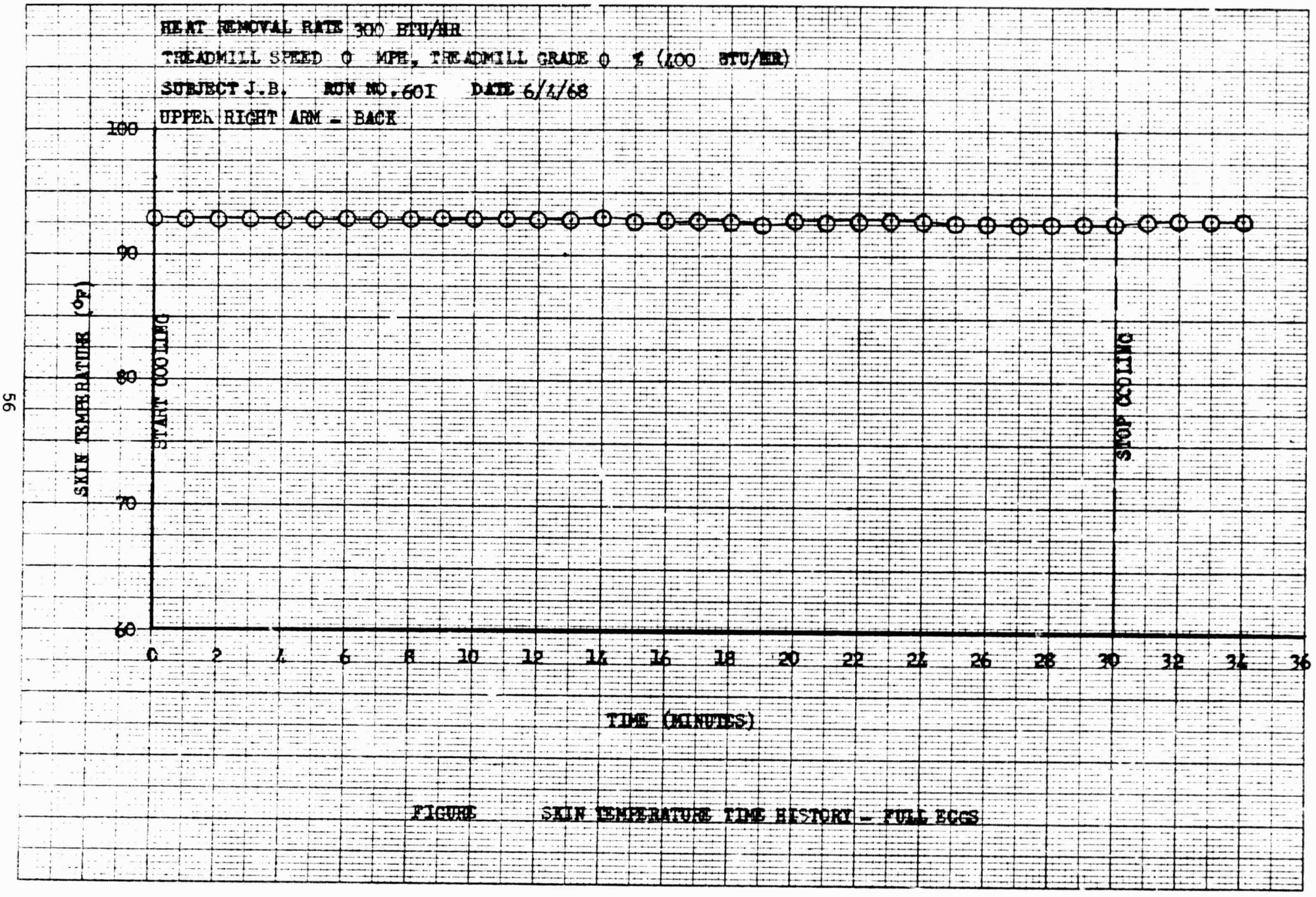


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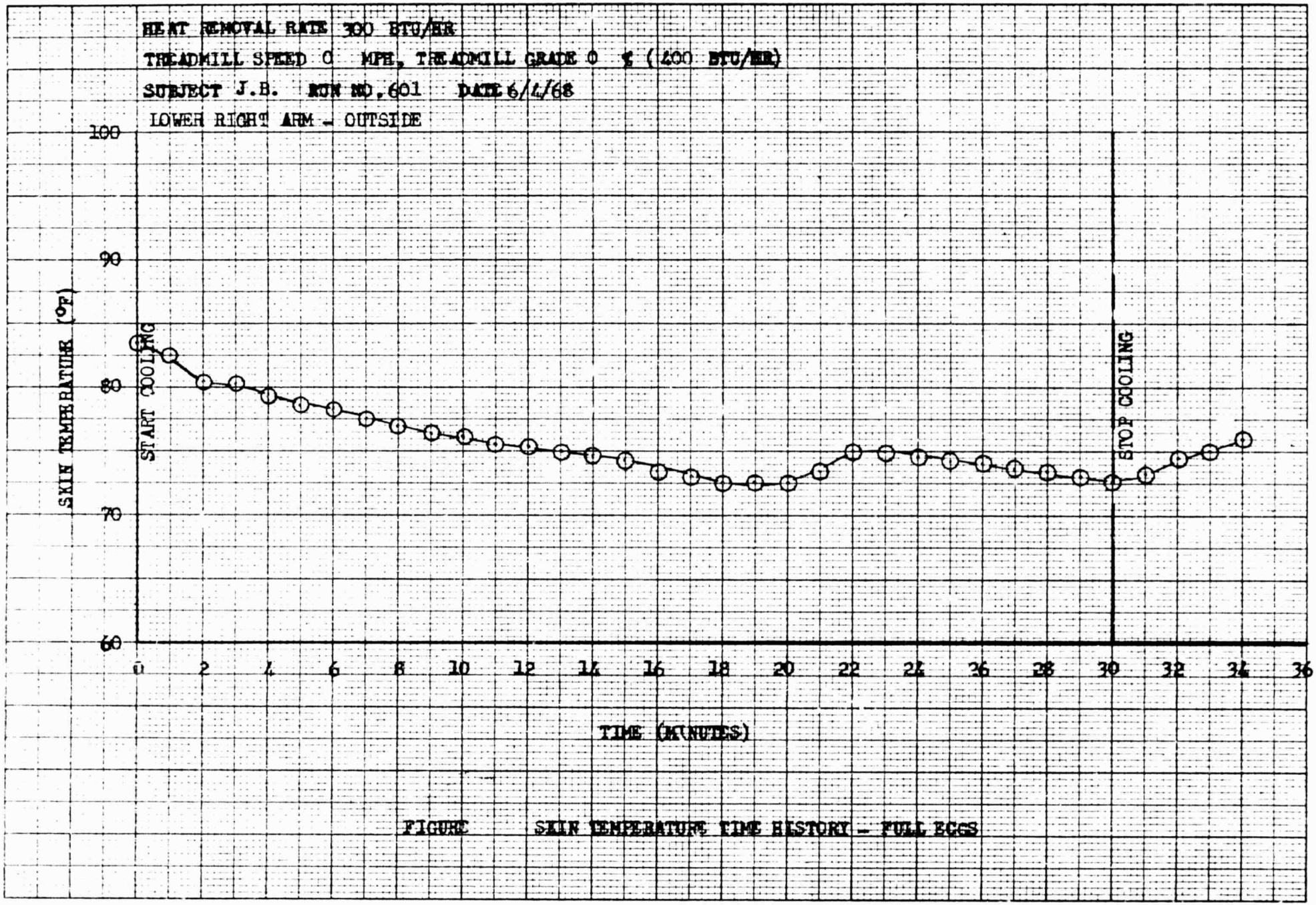


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

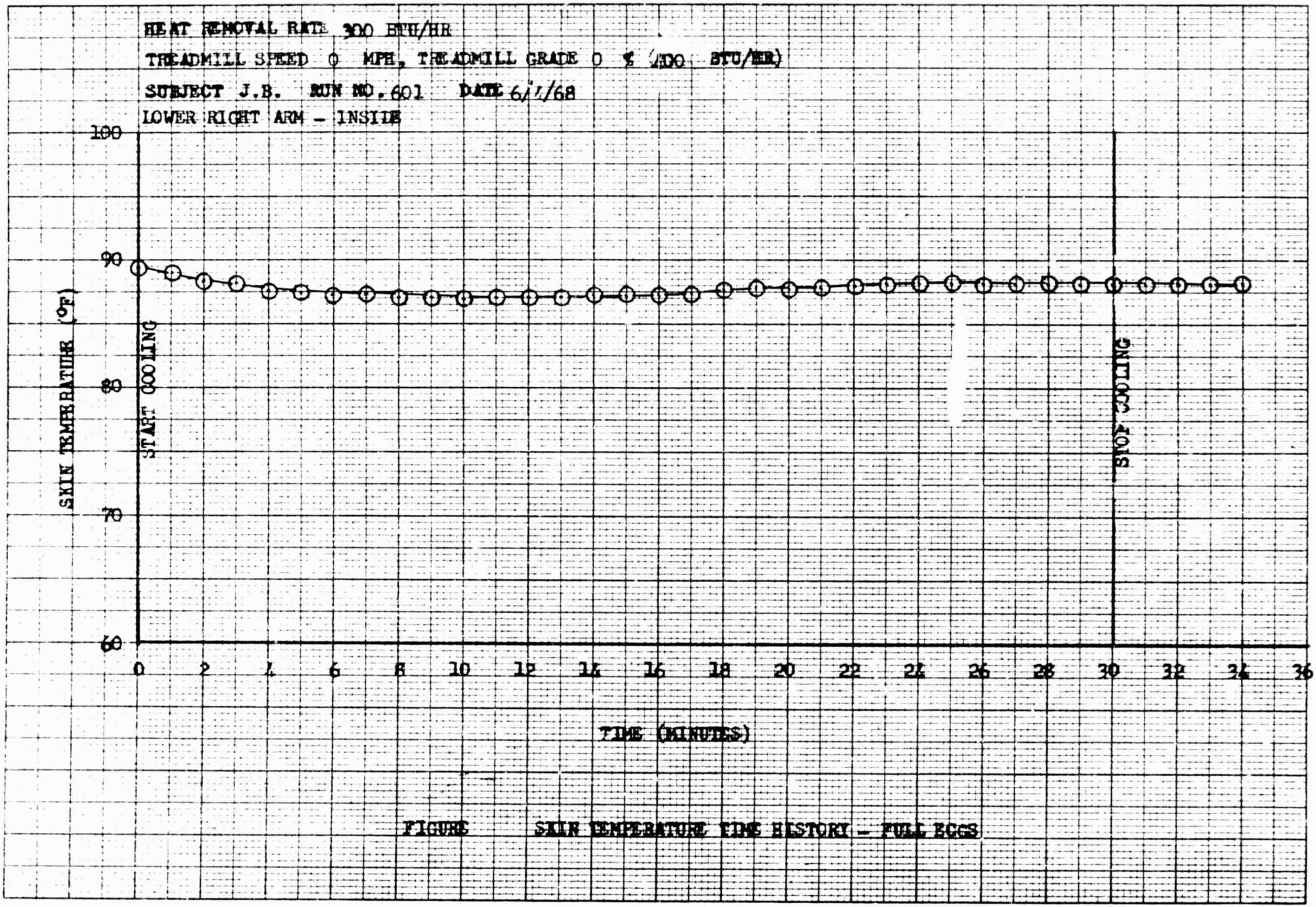


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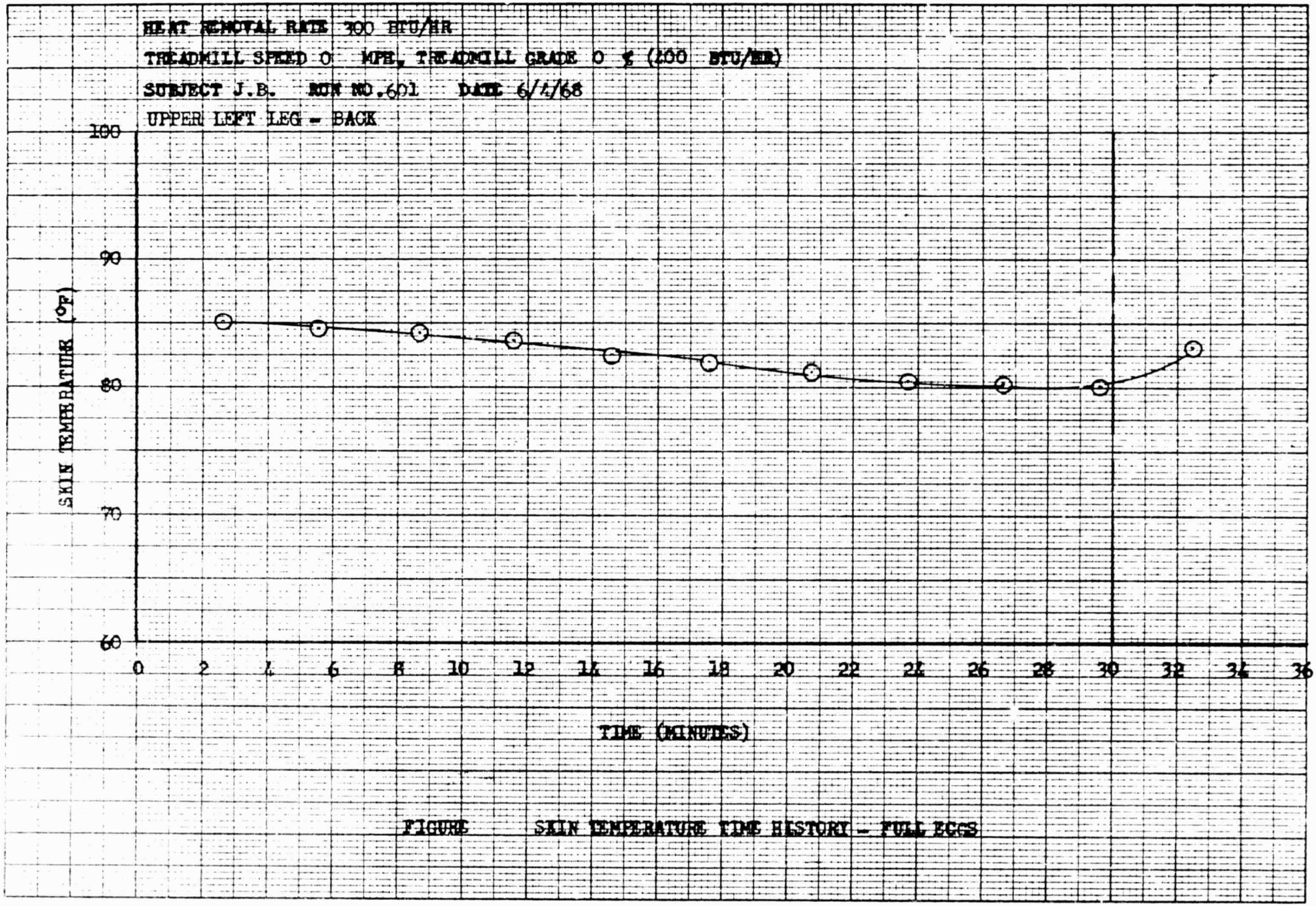


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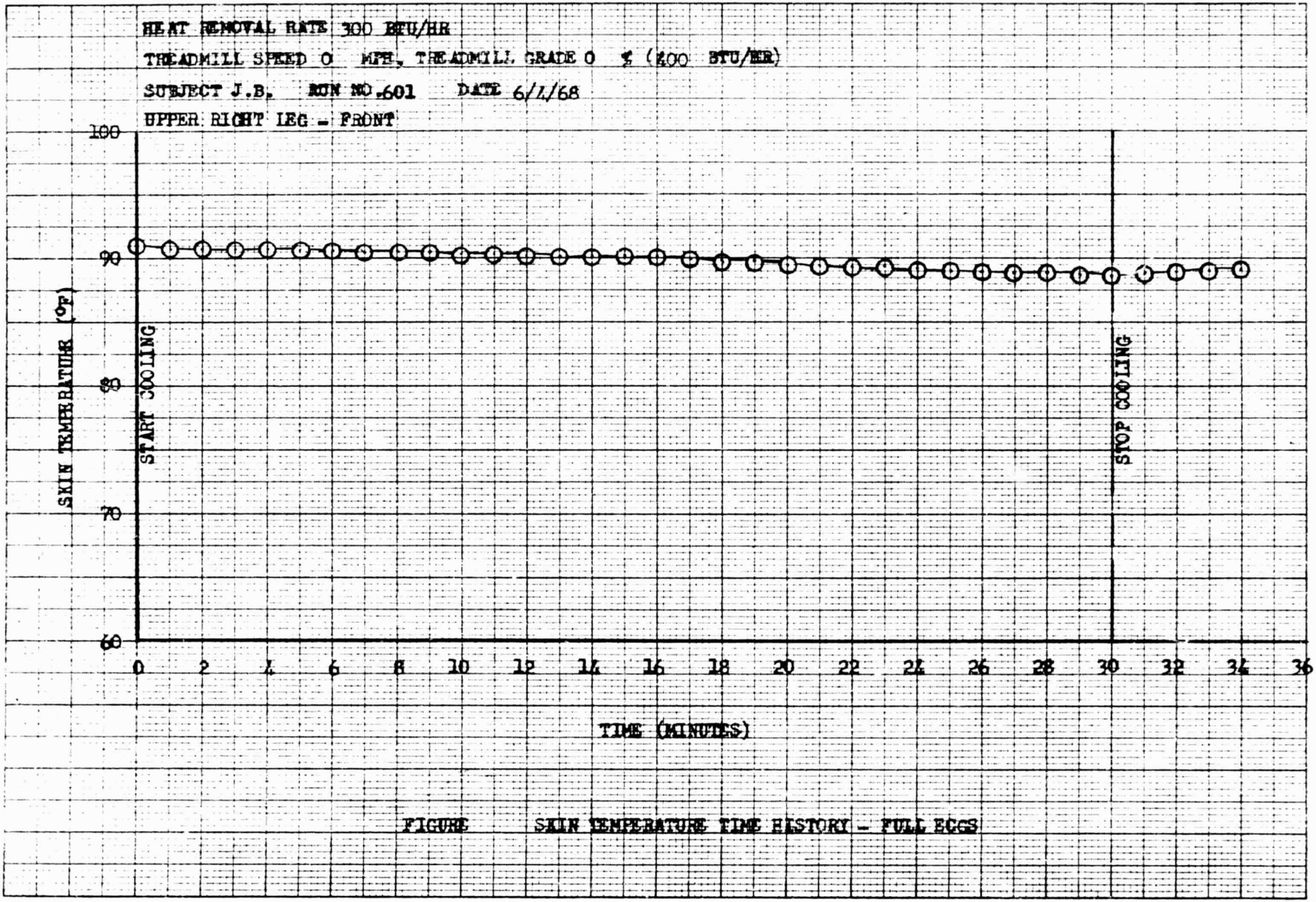


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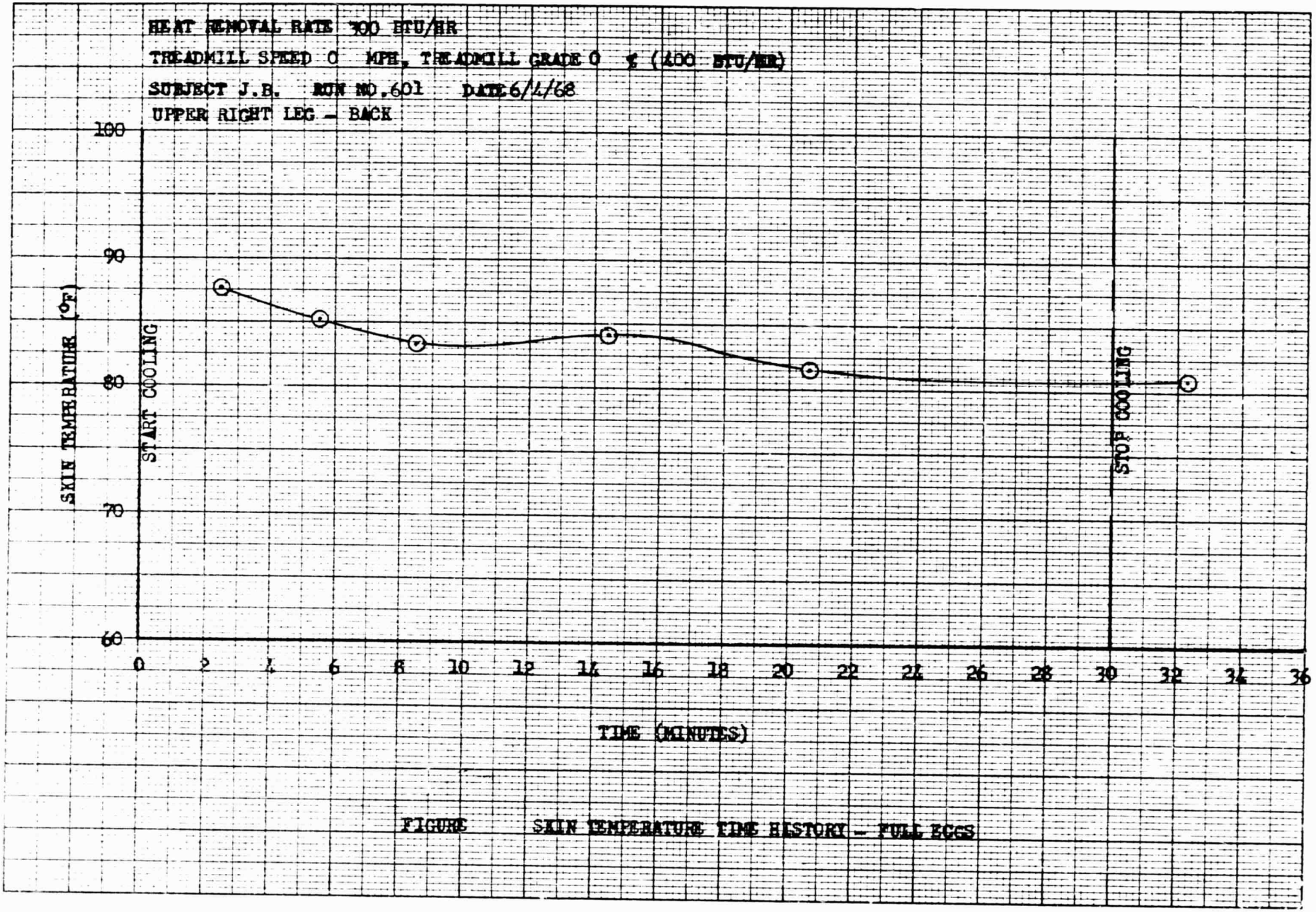


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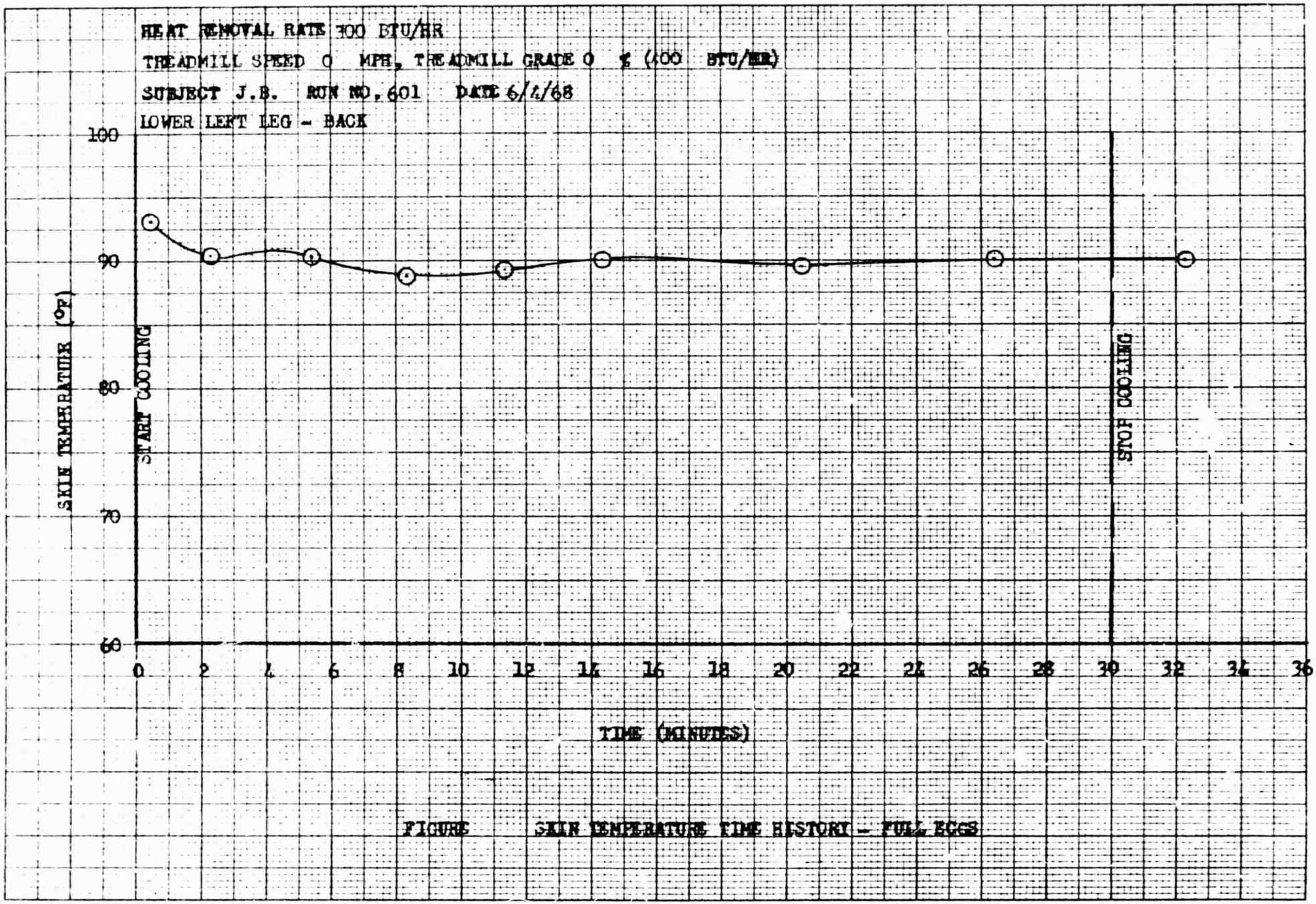


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

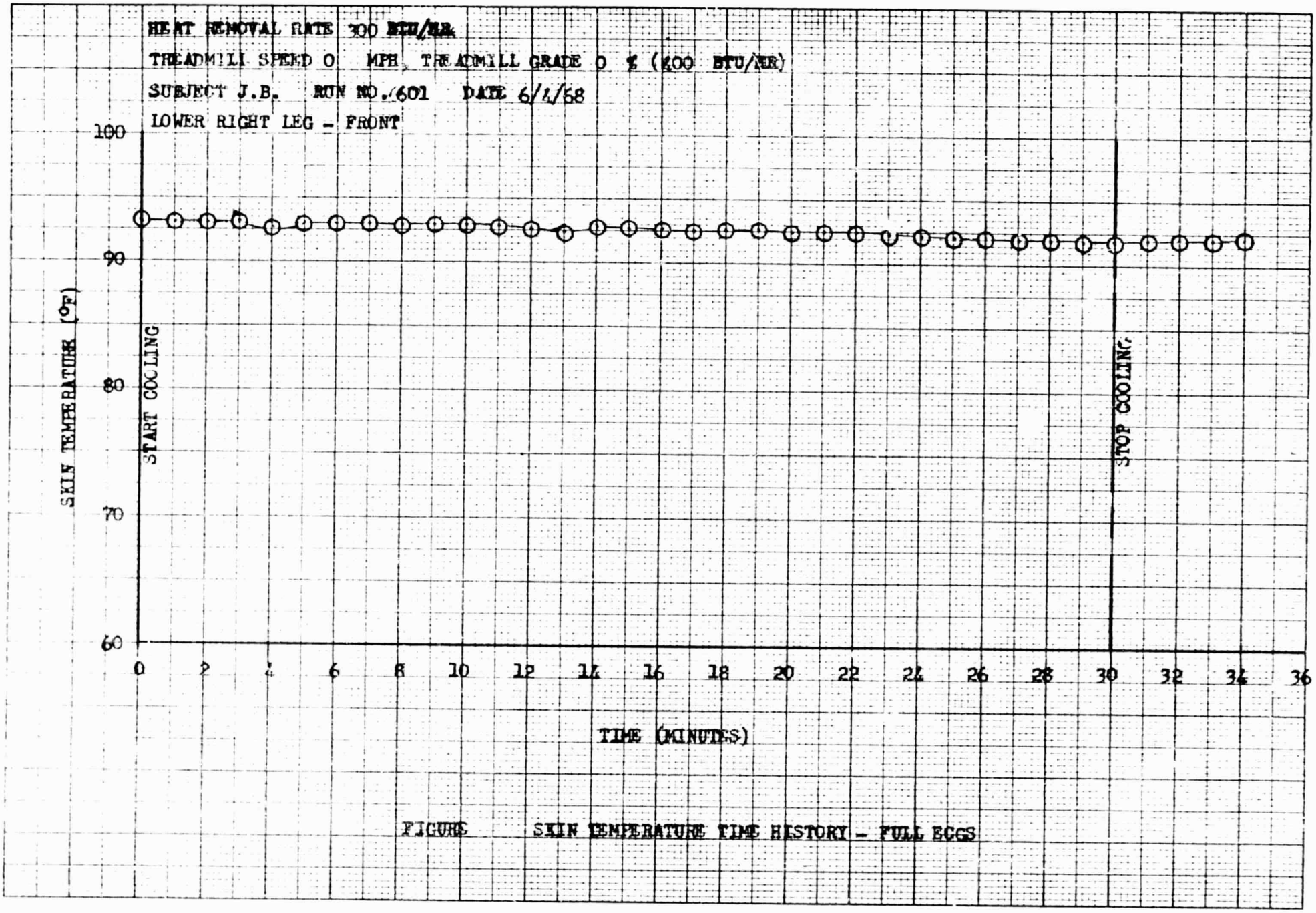


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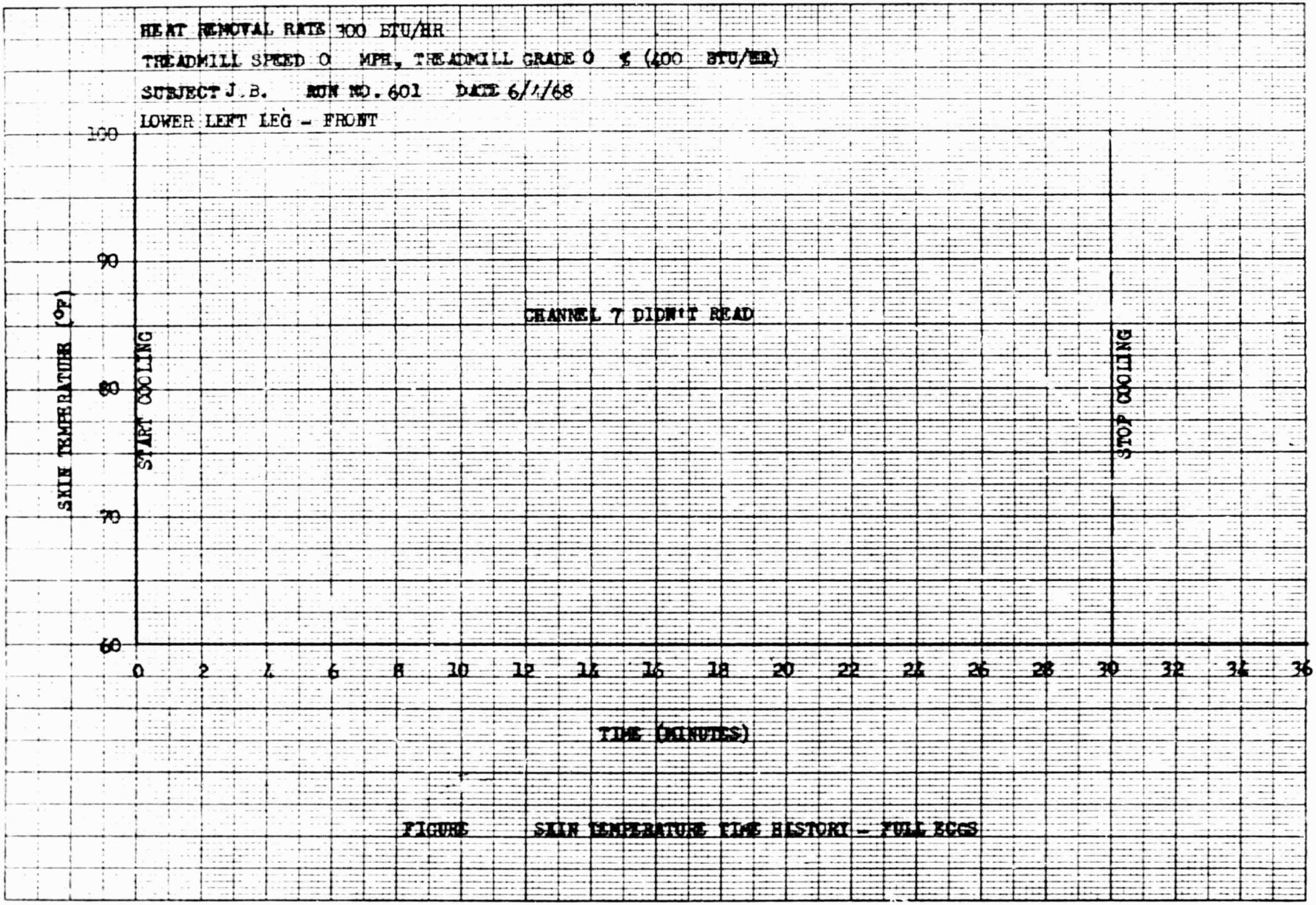


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

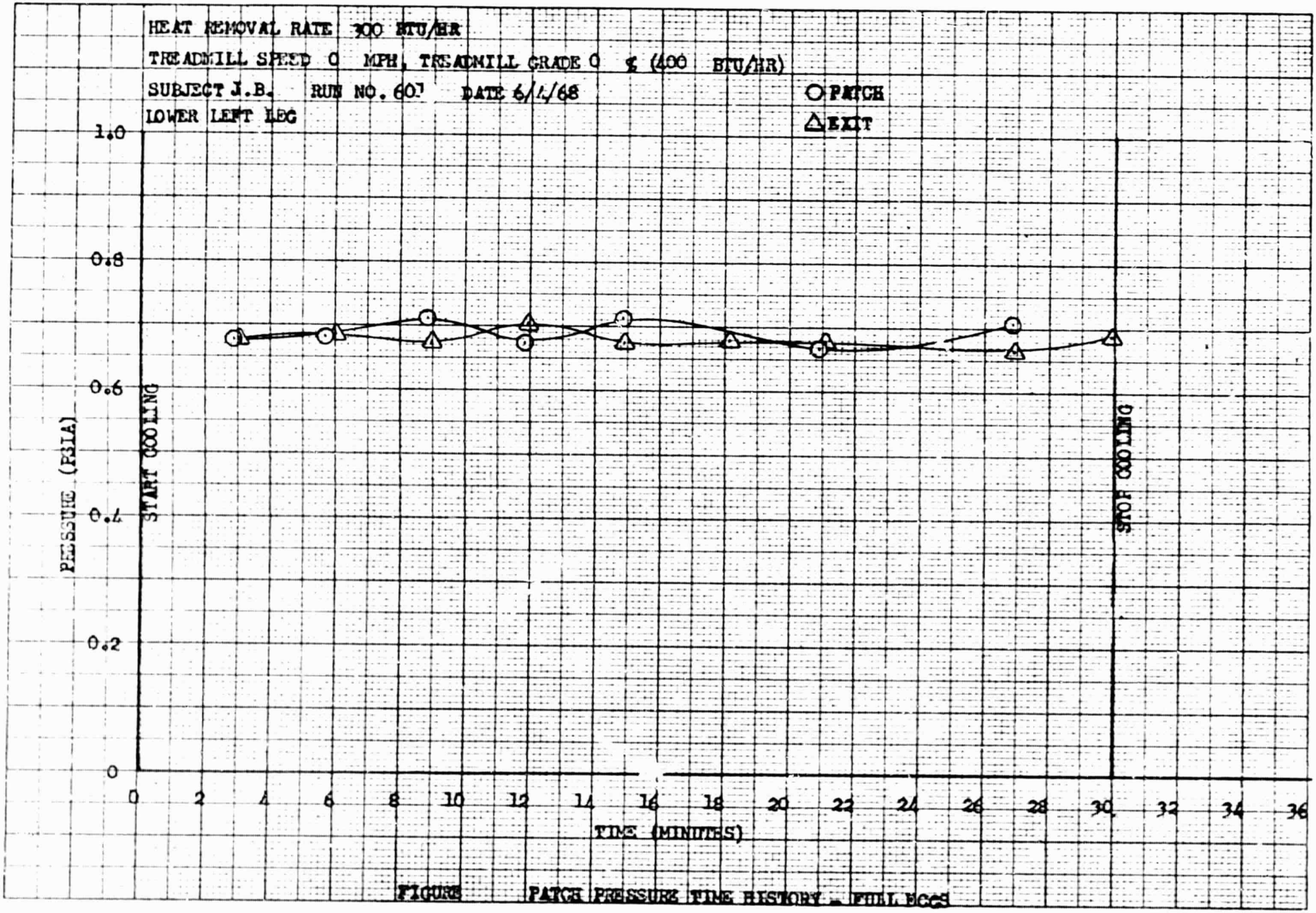


FIGURE PATCH PRESSURE TIME HISTORY - FULL EGGS

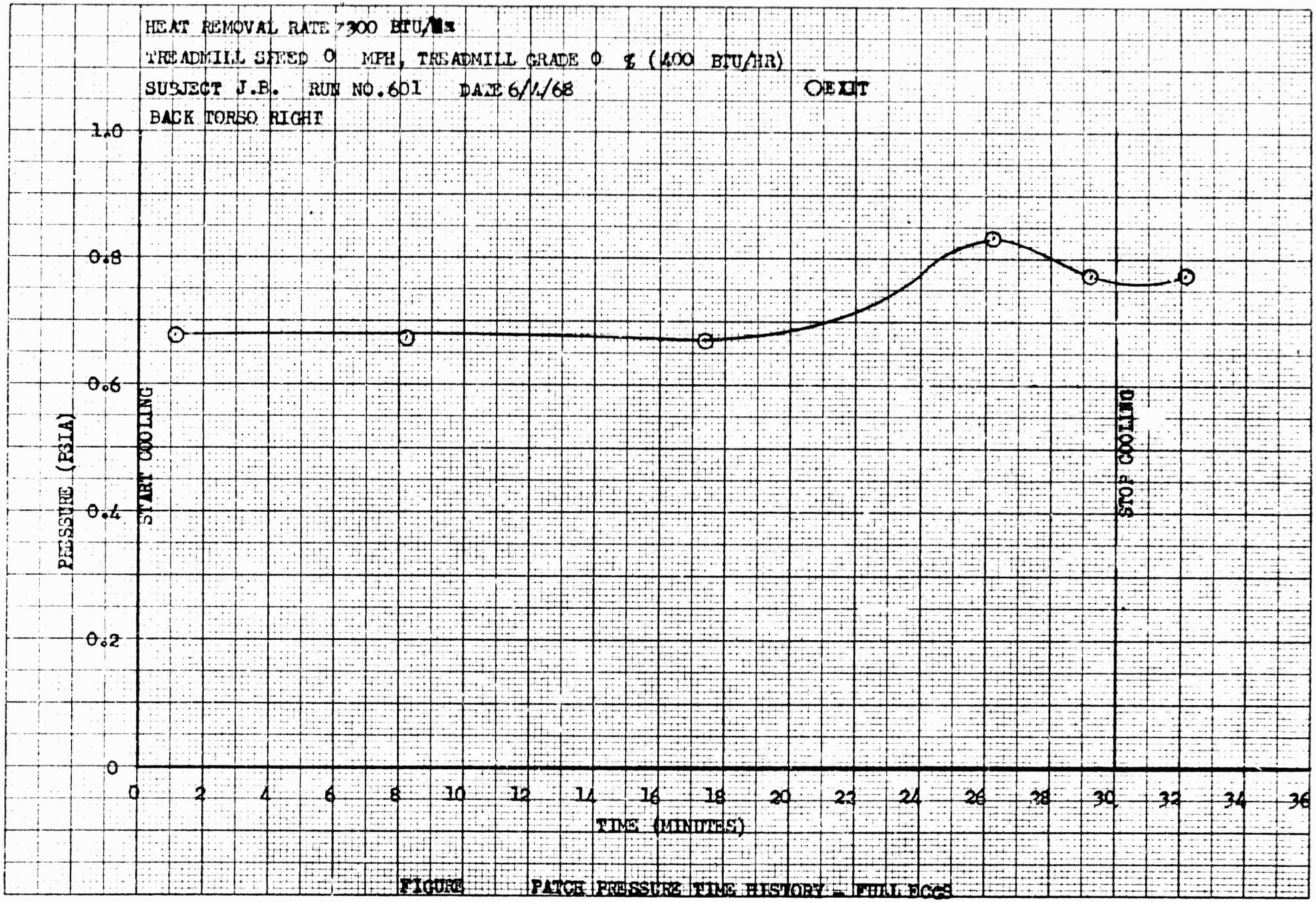


FIGURE PATCH PRESSURE TIME HISTORY - FULL ECGS

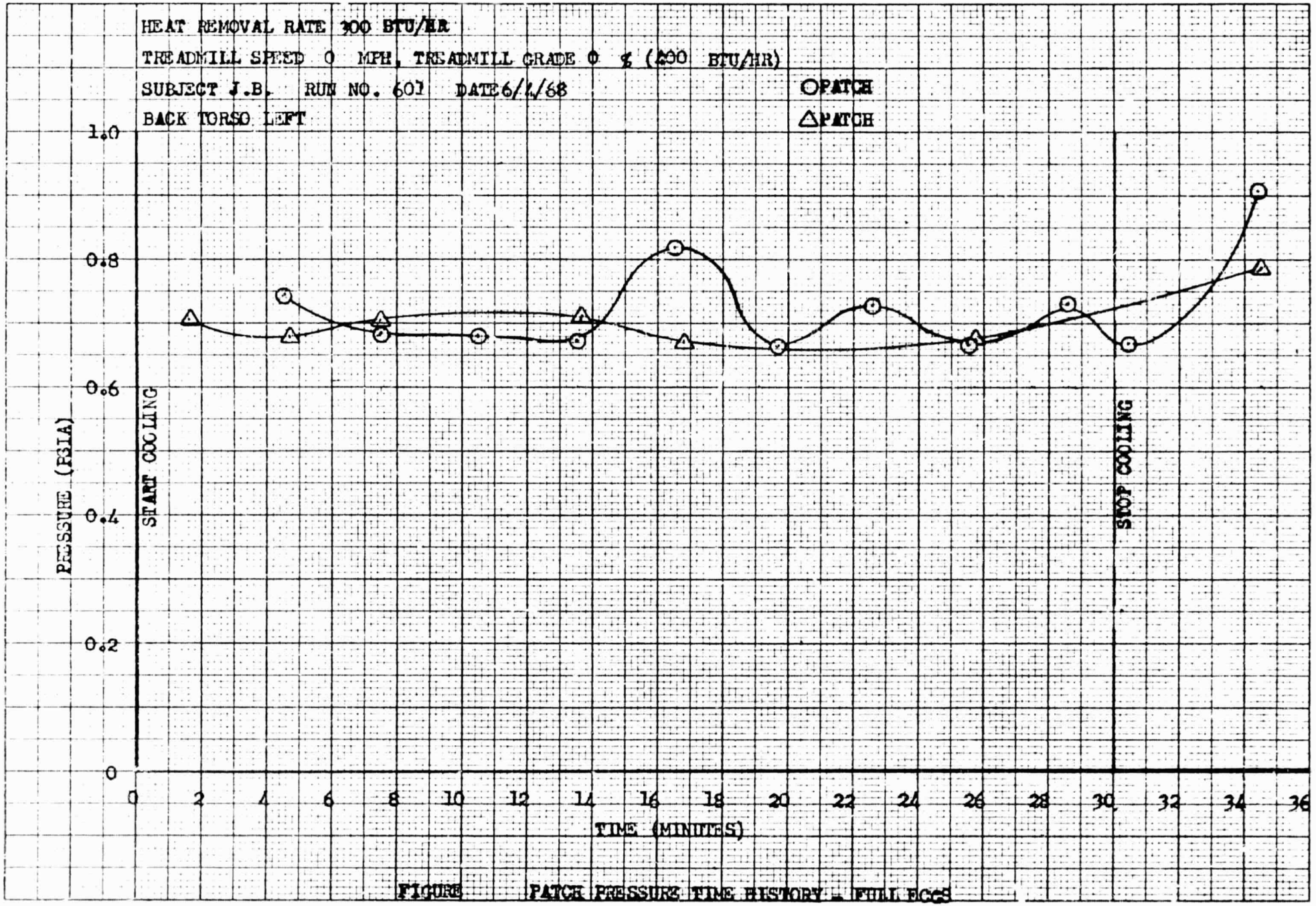


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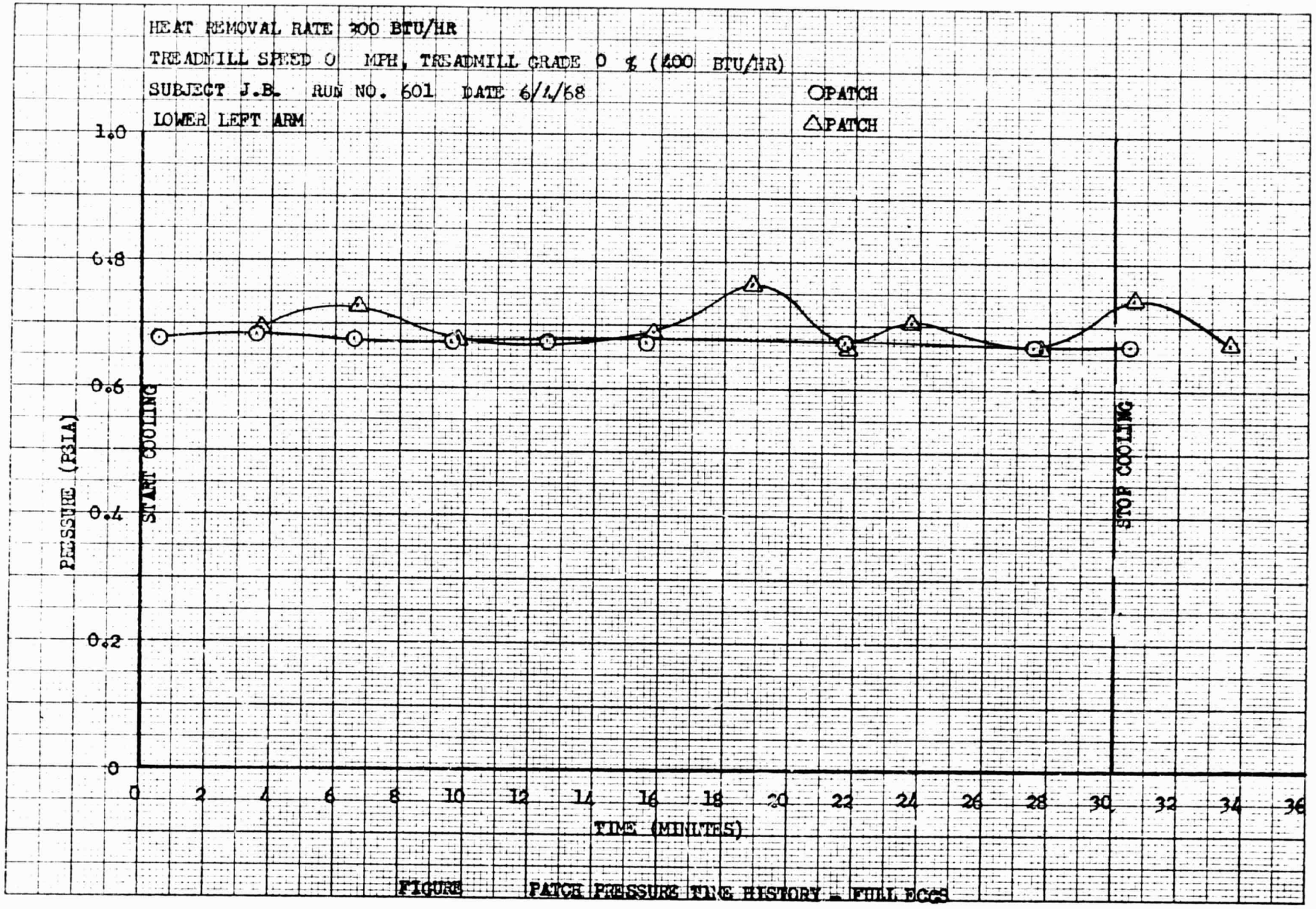


FIGURE PATCH PRESSURE TIME HISTORY - FULL ECG

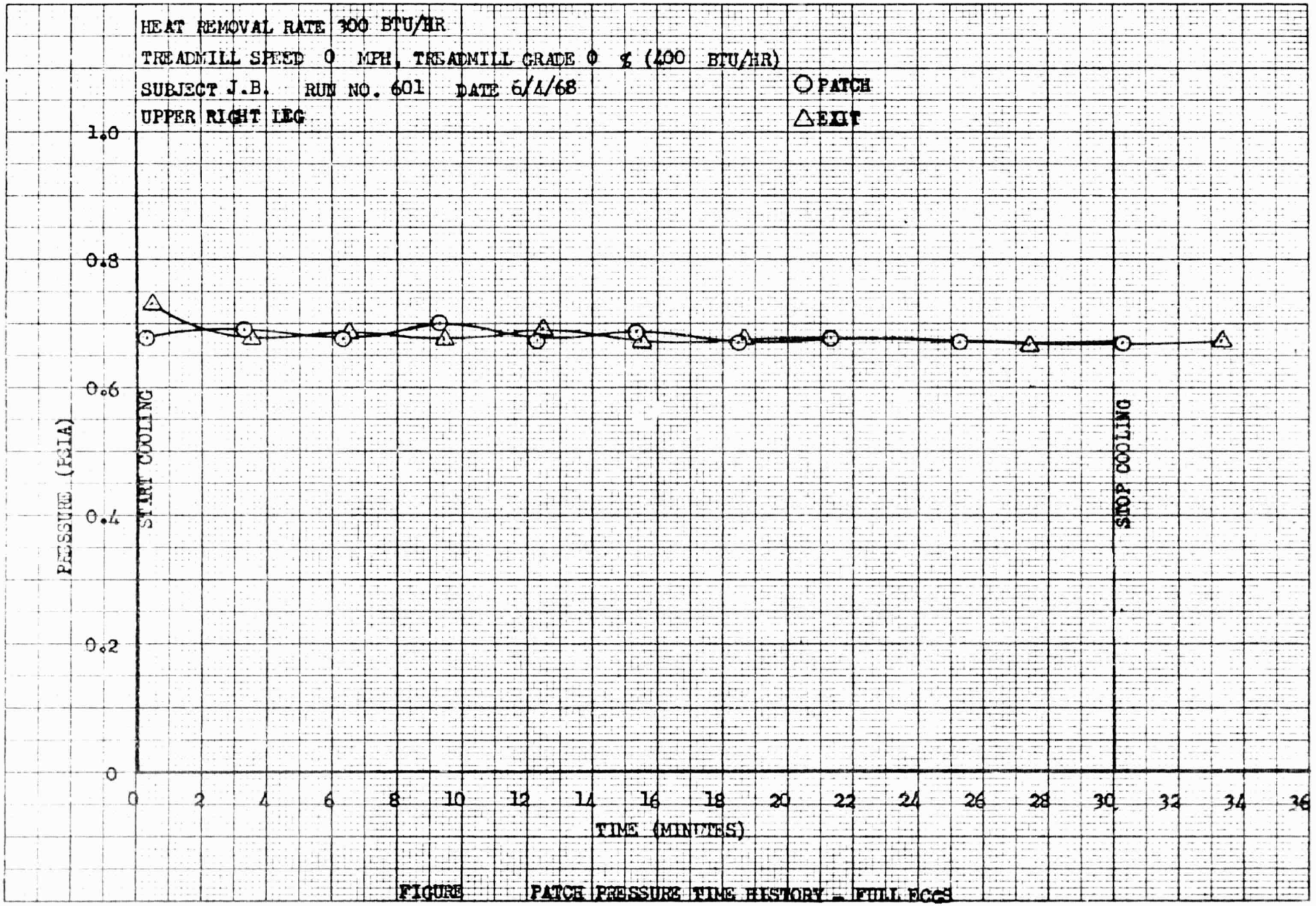


FIGURE PATCH PRESSURE TIME HISTORY - FULL PCGS

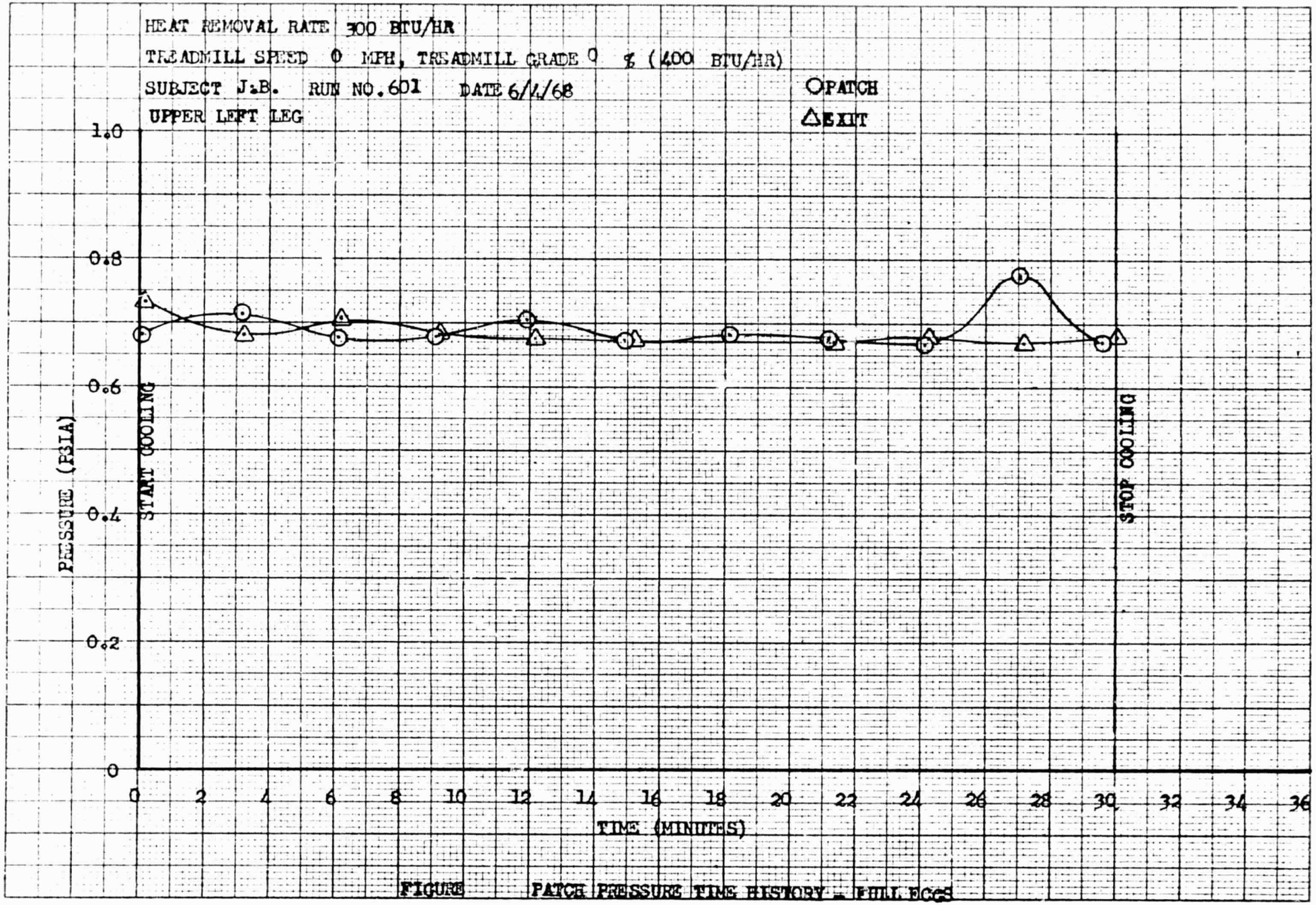


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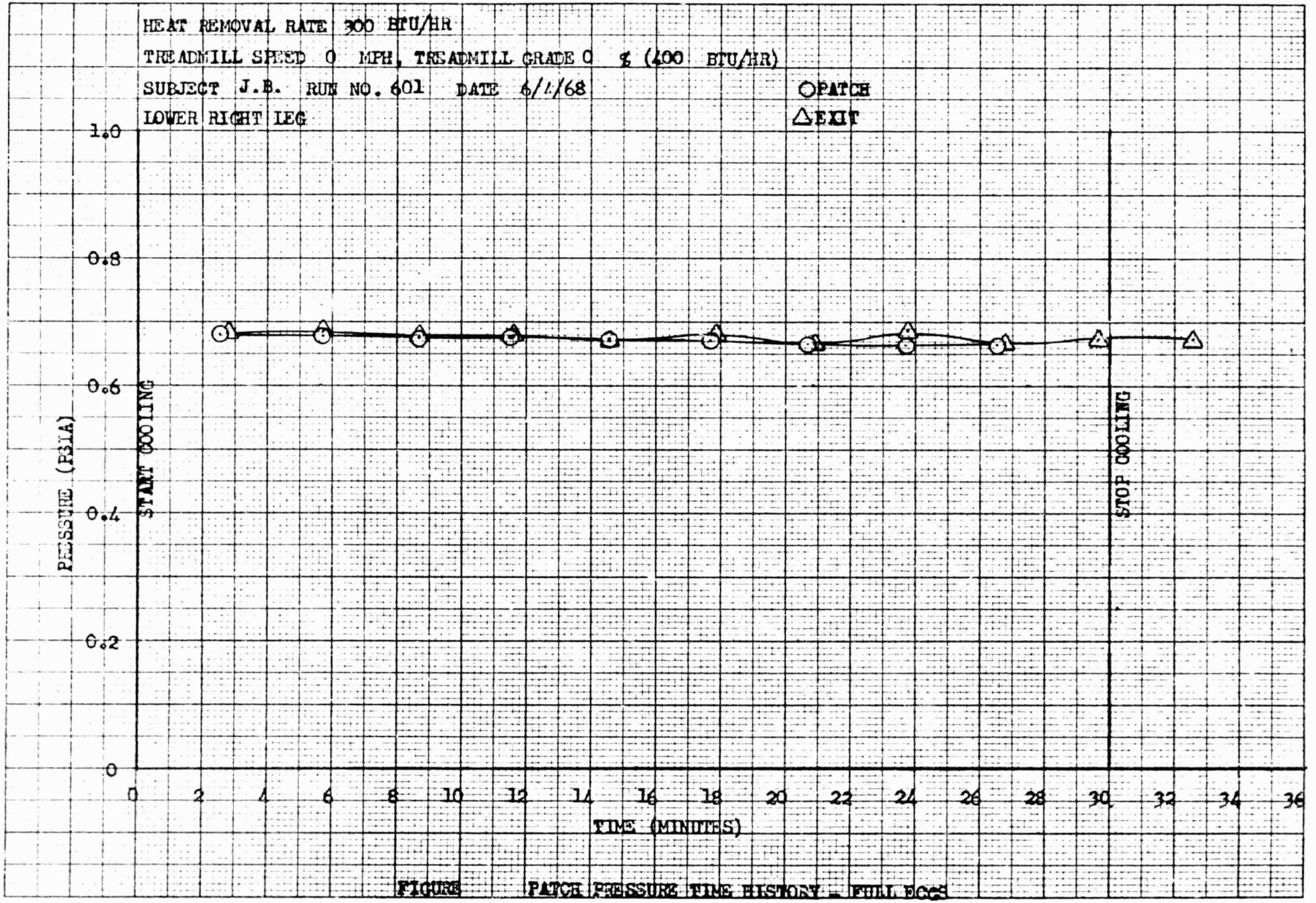


FIGURE PATCH PRESSURE TIME HISTORY - FULL ECG

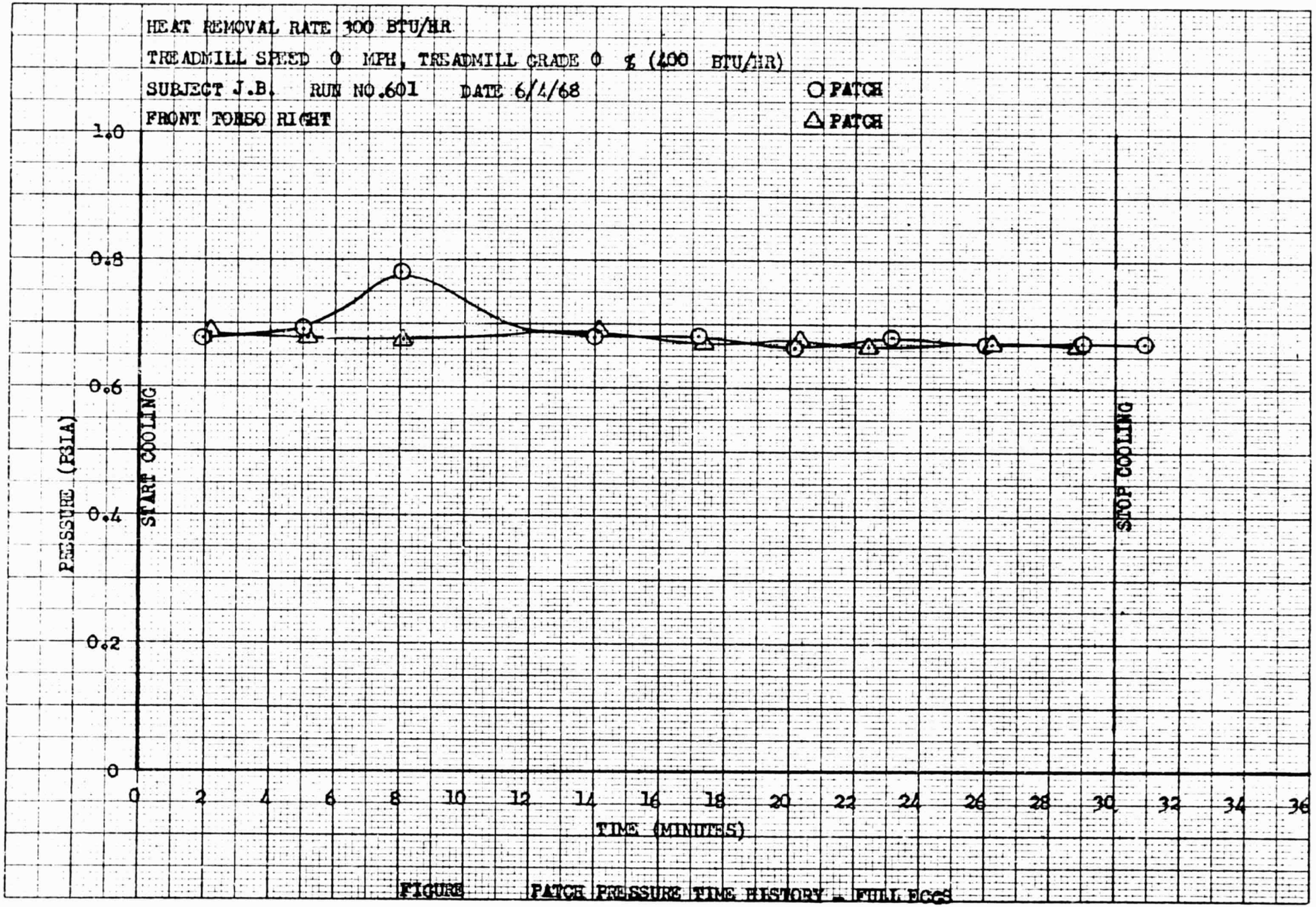


FIGURE PATCH PRESSURE TIME HISTORY - FULL EGGS

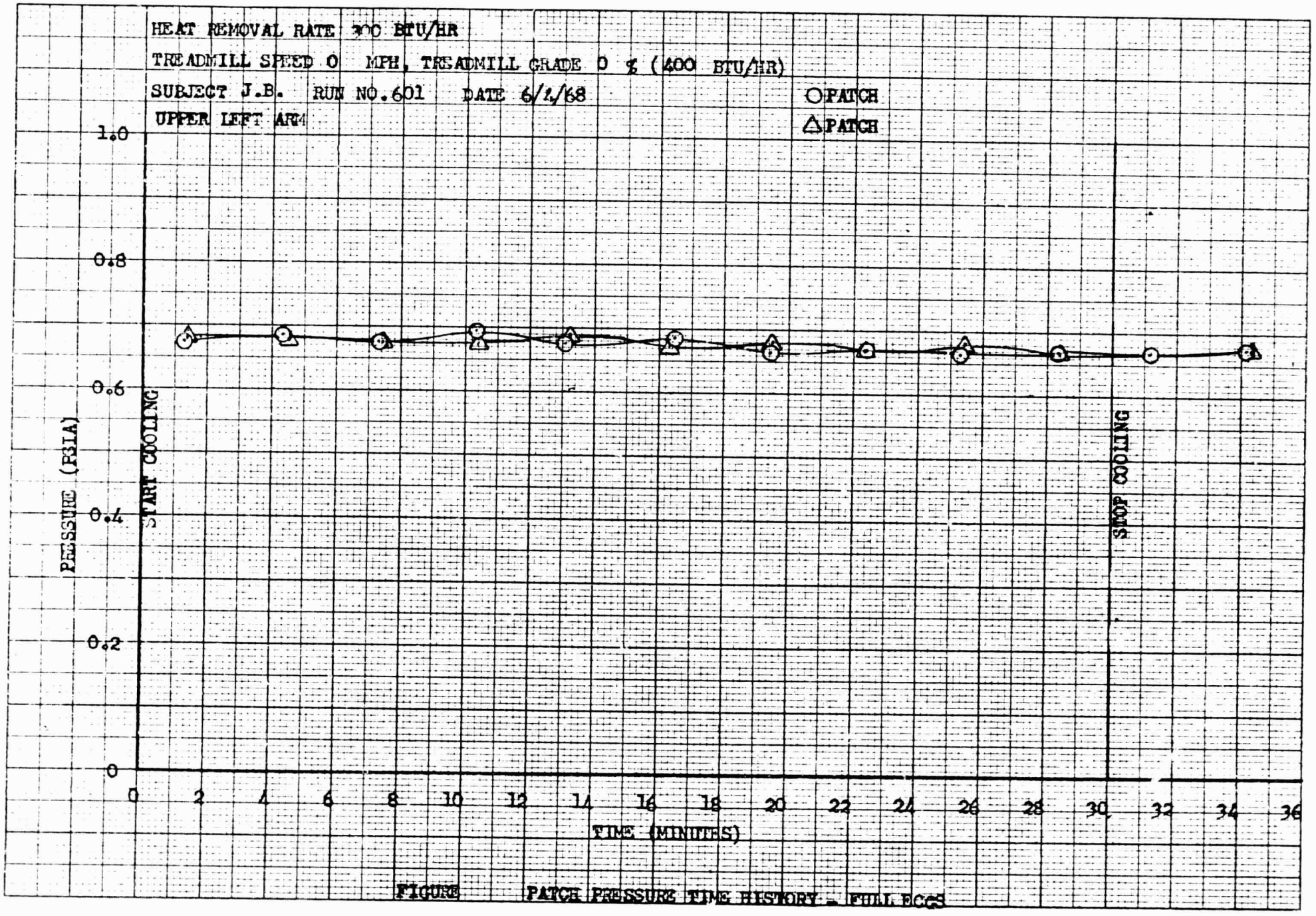


FIGURE PATCH PRESSURE TIME HISTORY - FULL ECCS

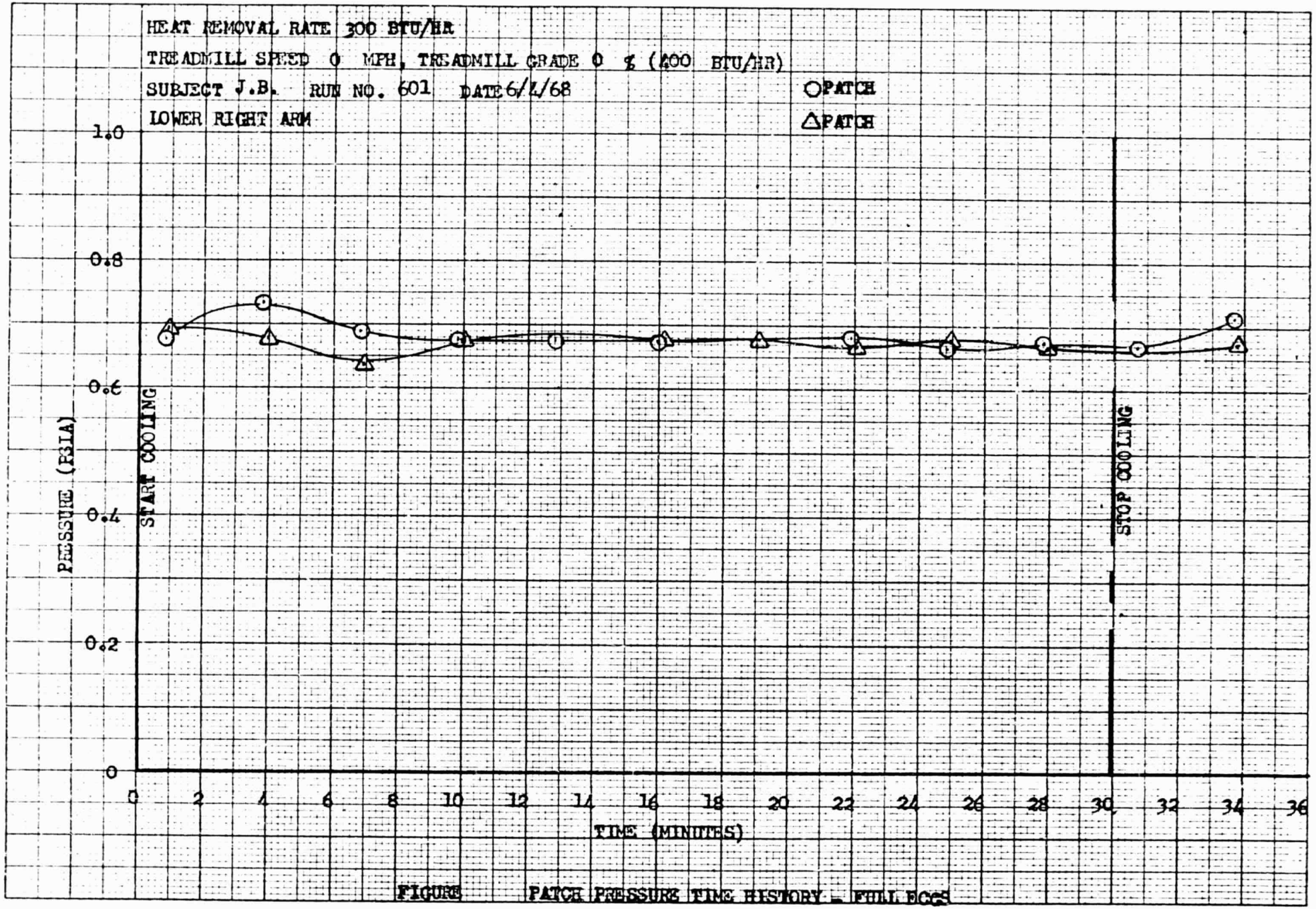


FIGURE PATCH PRESSURE TIME HISTORY - FULL ECCS

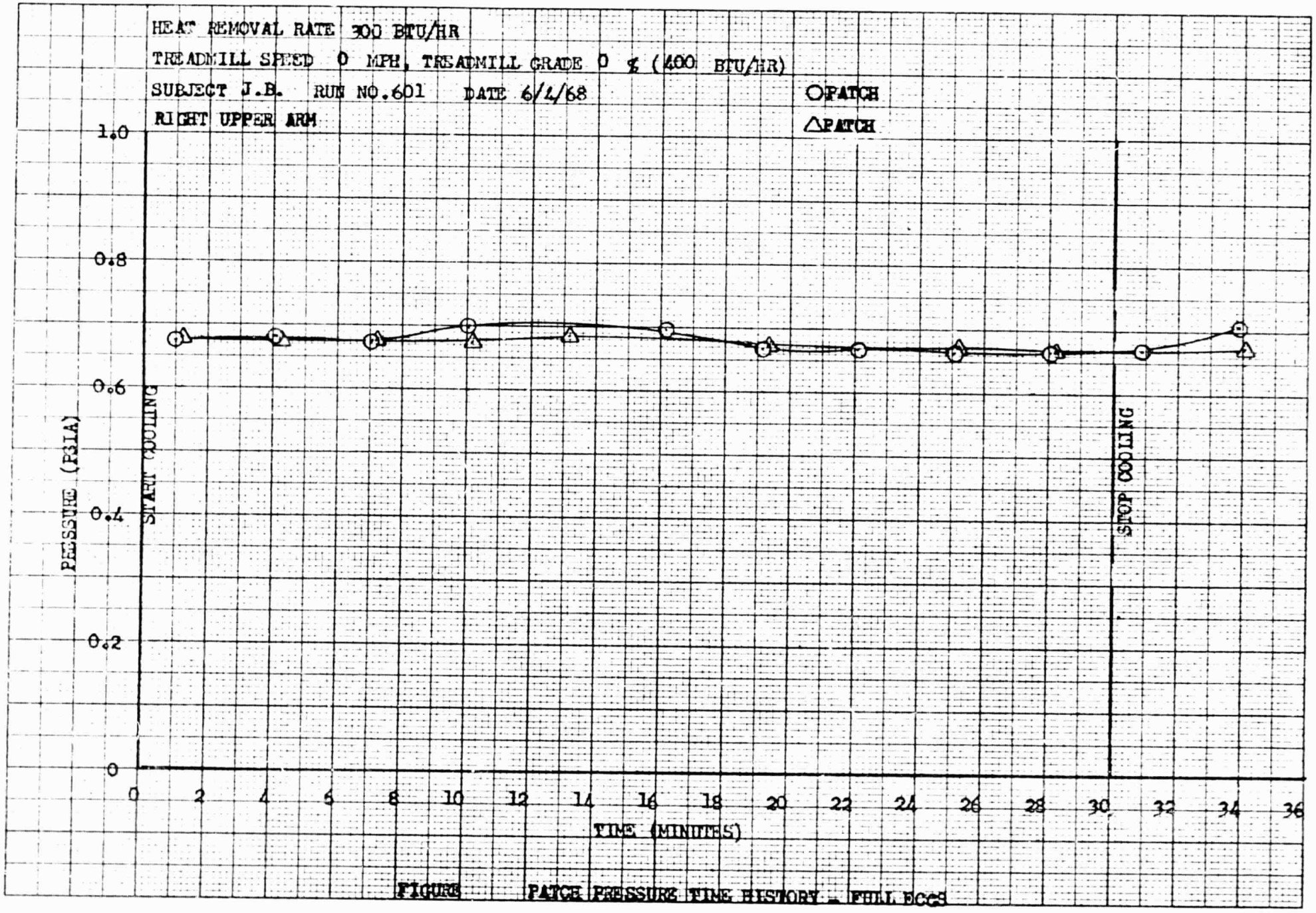


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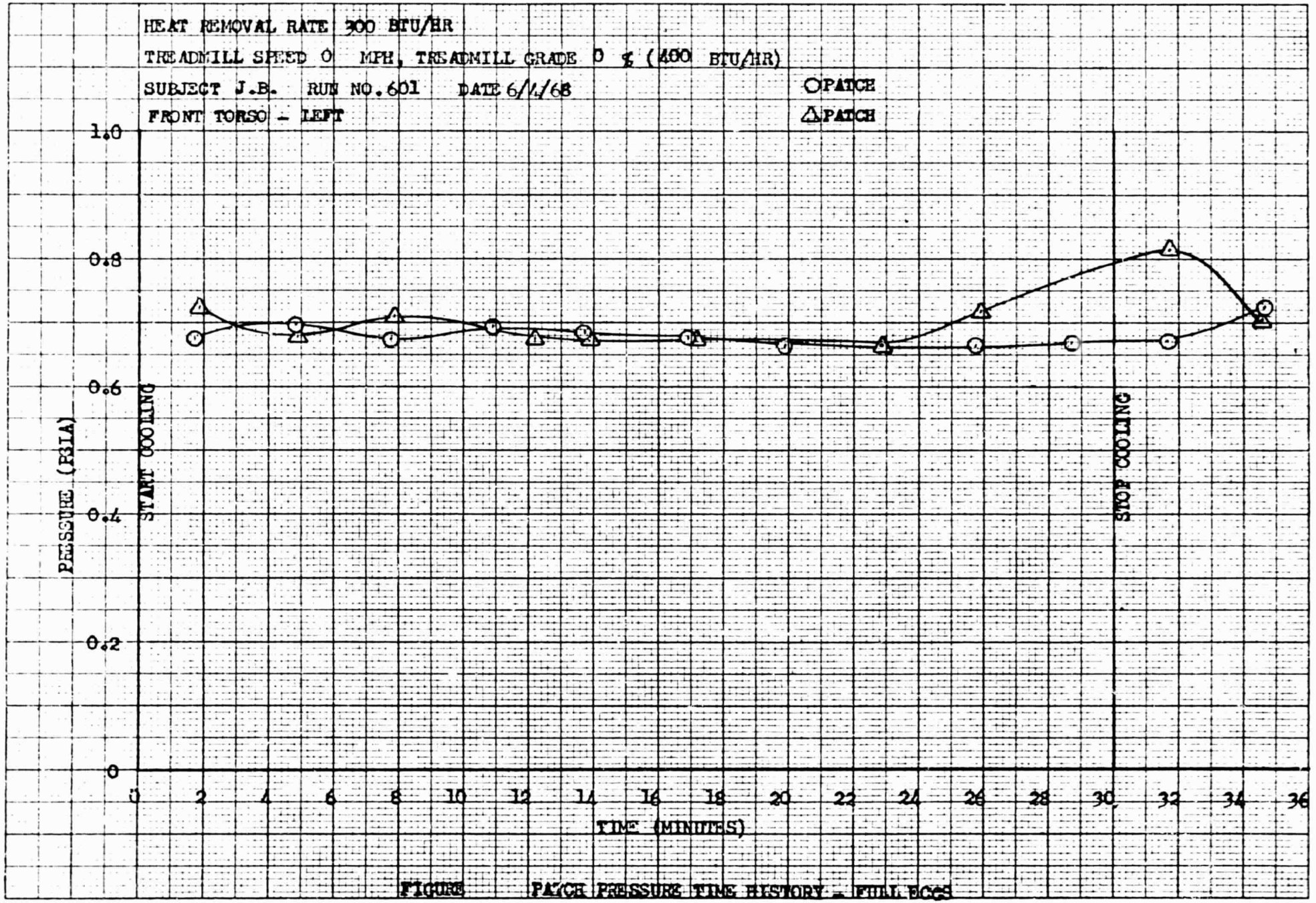


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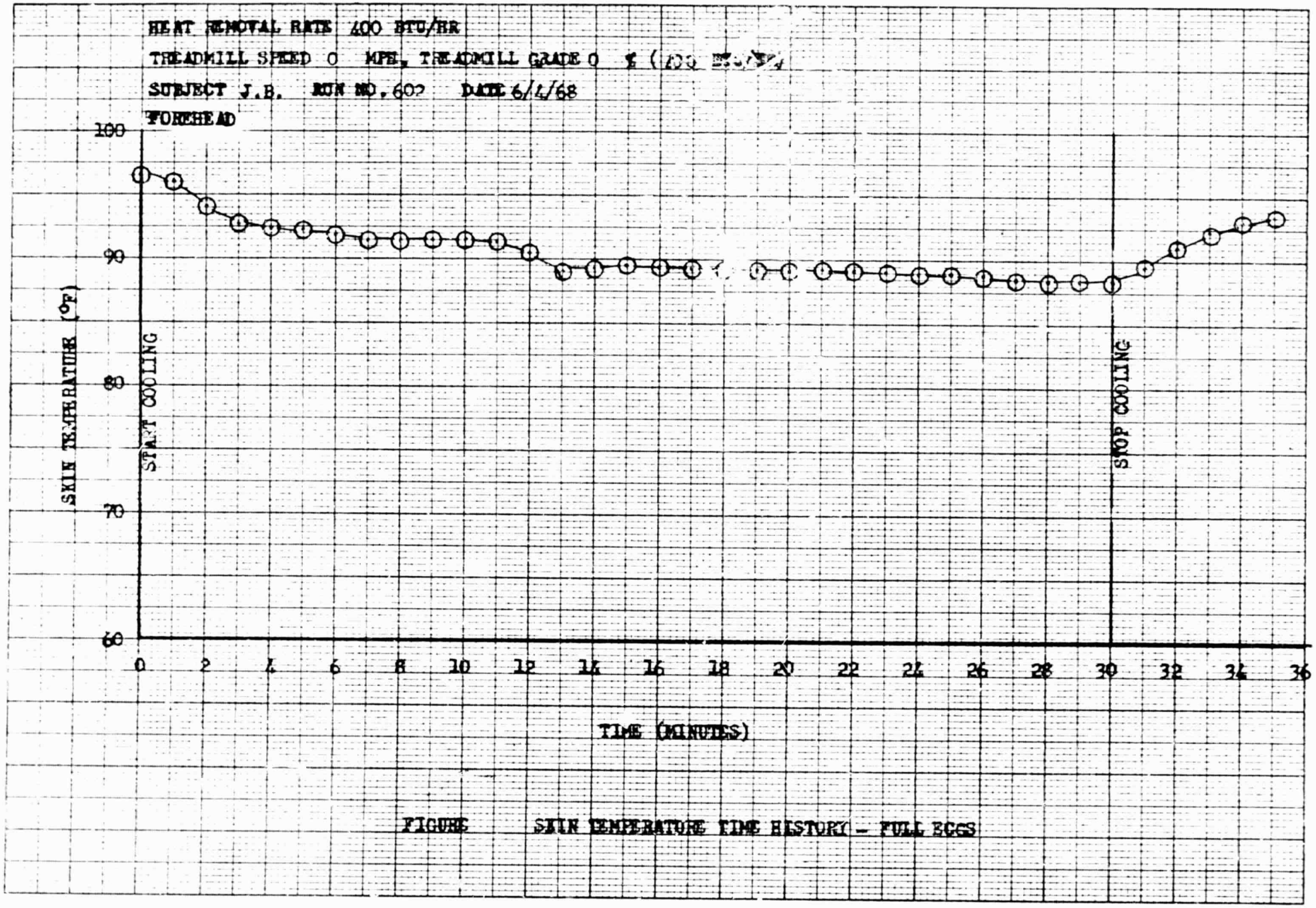


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL EGGS

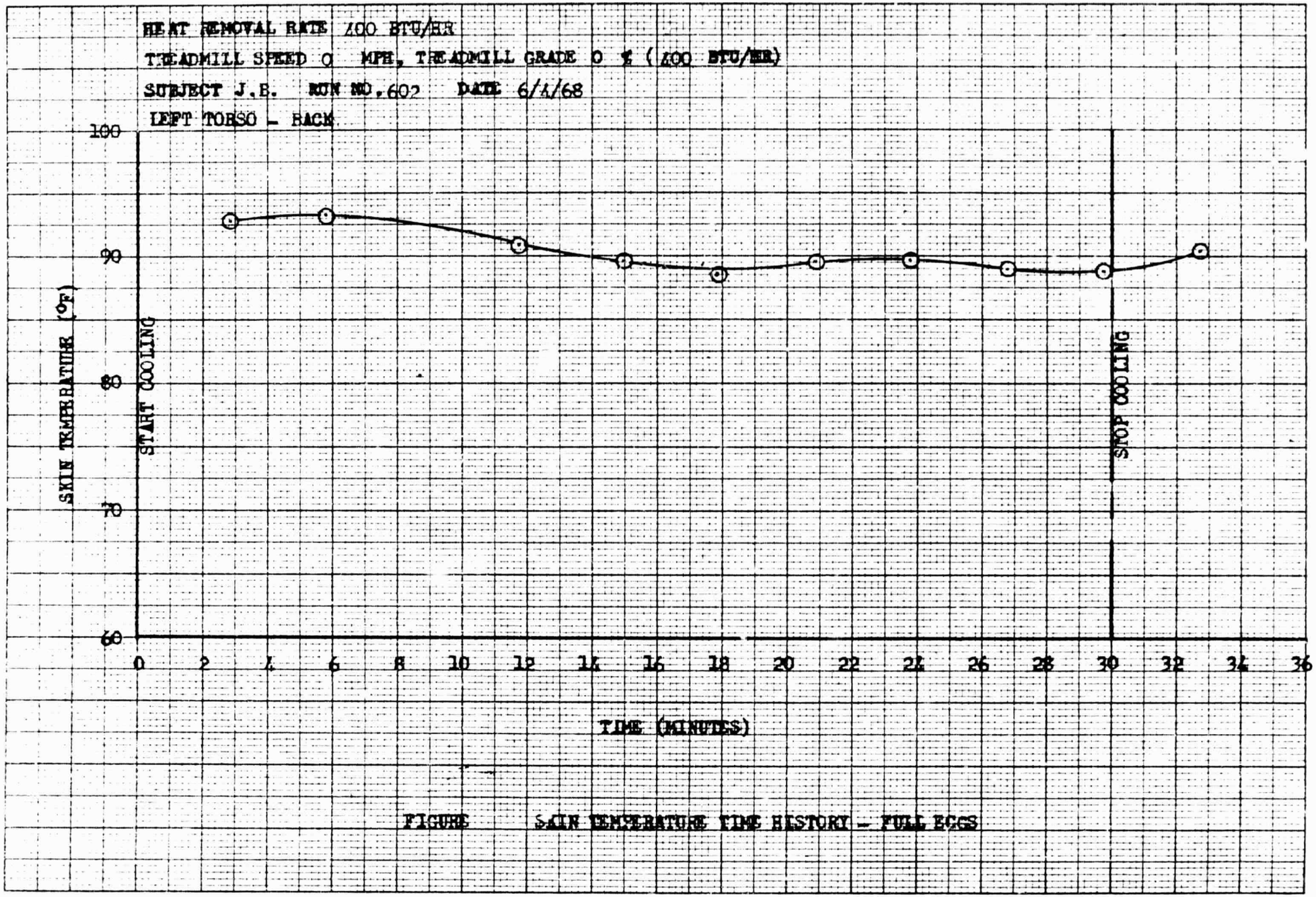


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL EGGS

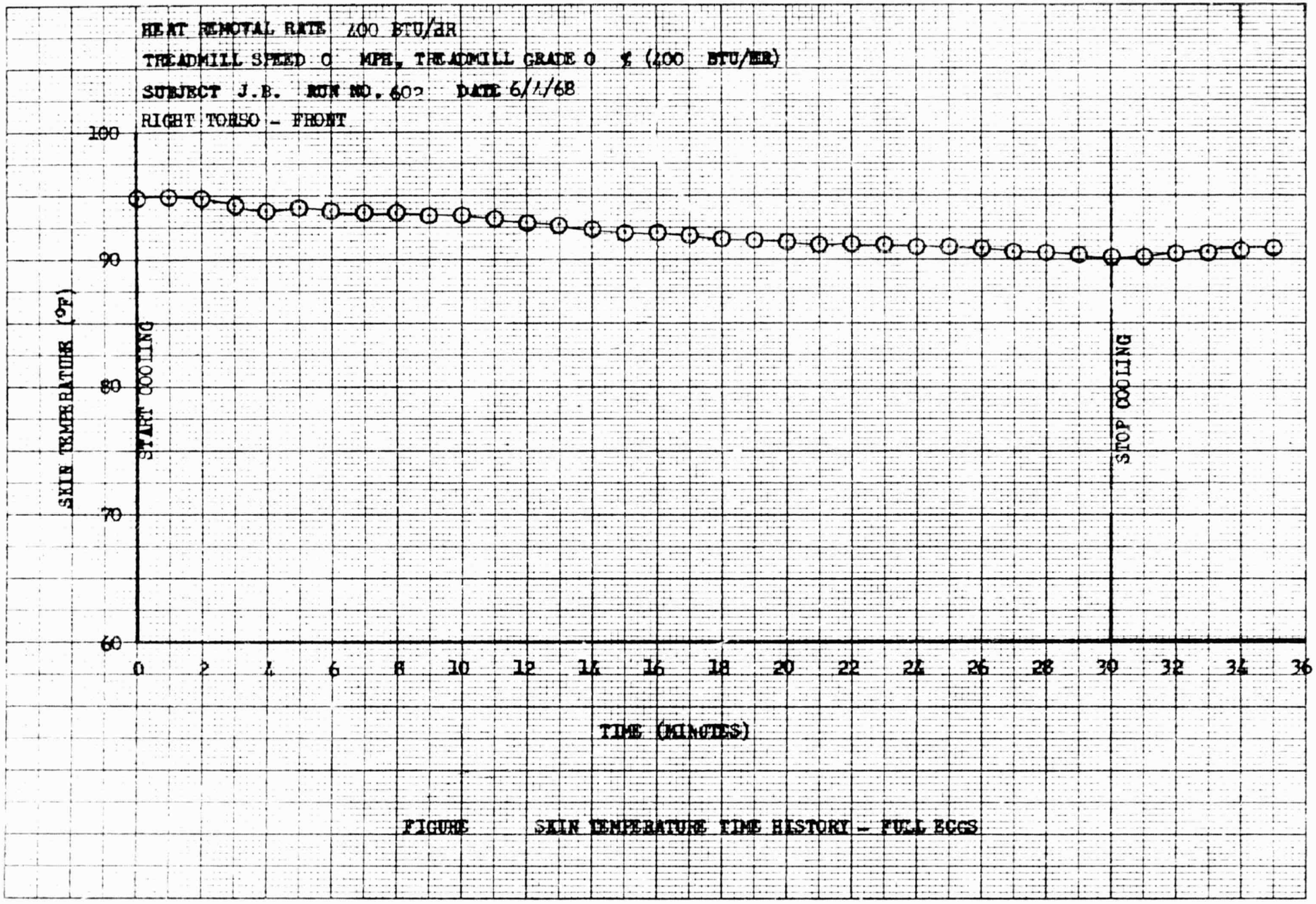


FIGURE SKIN TEMPERATURE TIME HISTORY – FULL ECGS

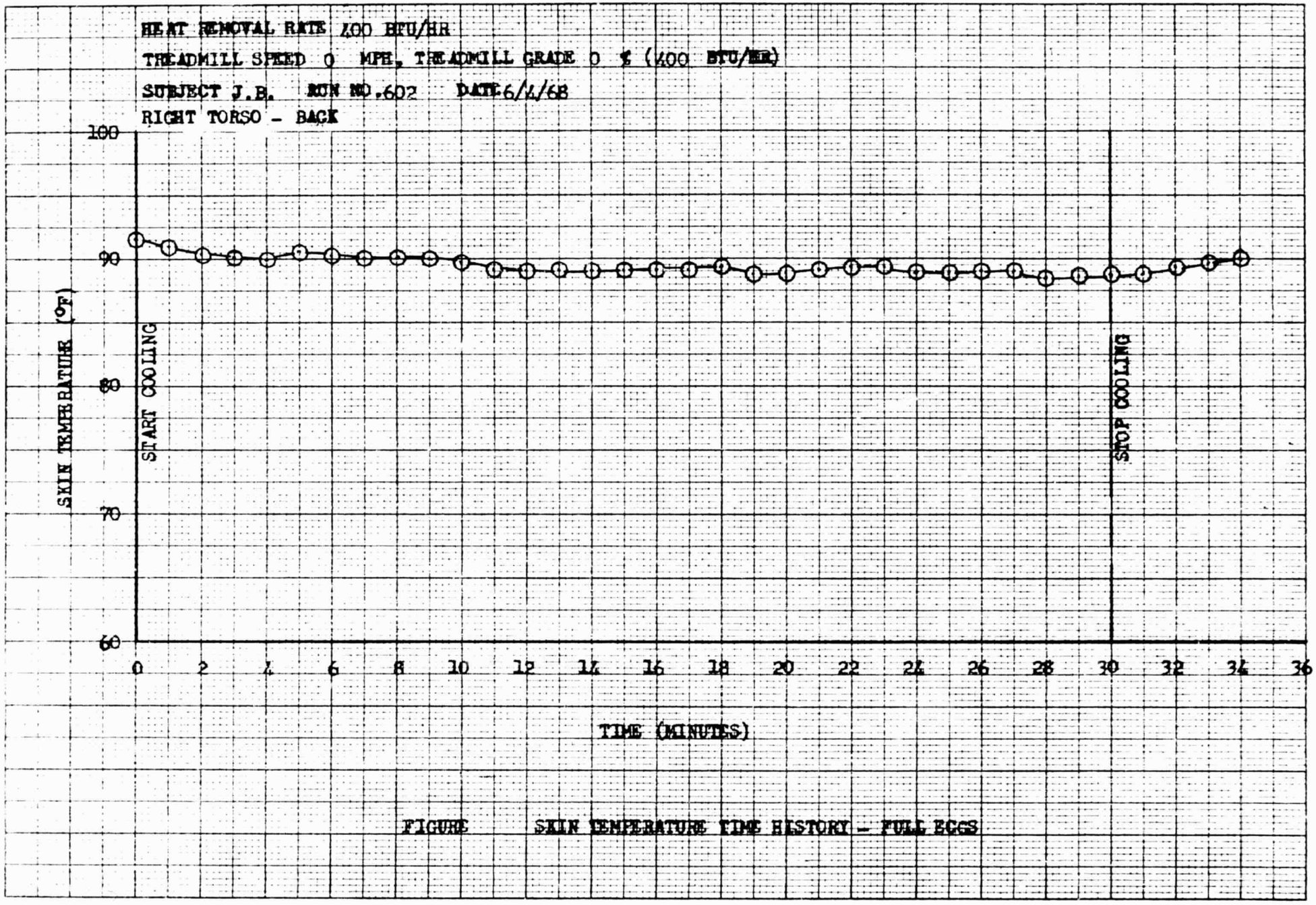


FIGURE SKIN TEMPERATURE TIME HISTORY – FULL EGGS

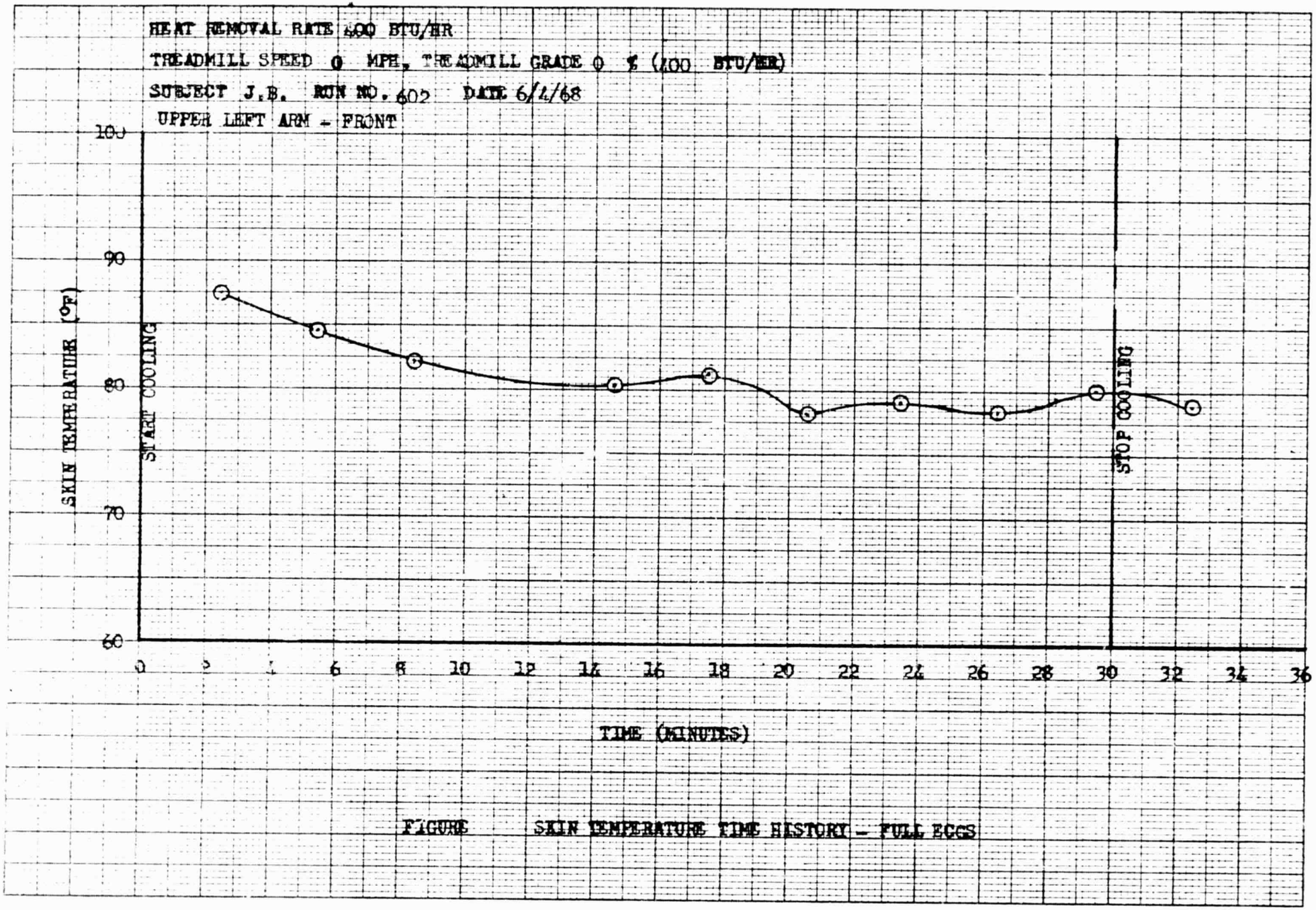


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

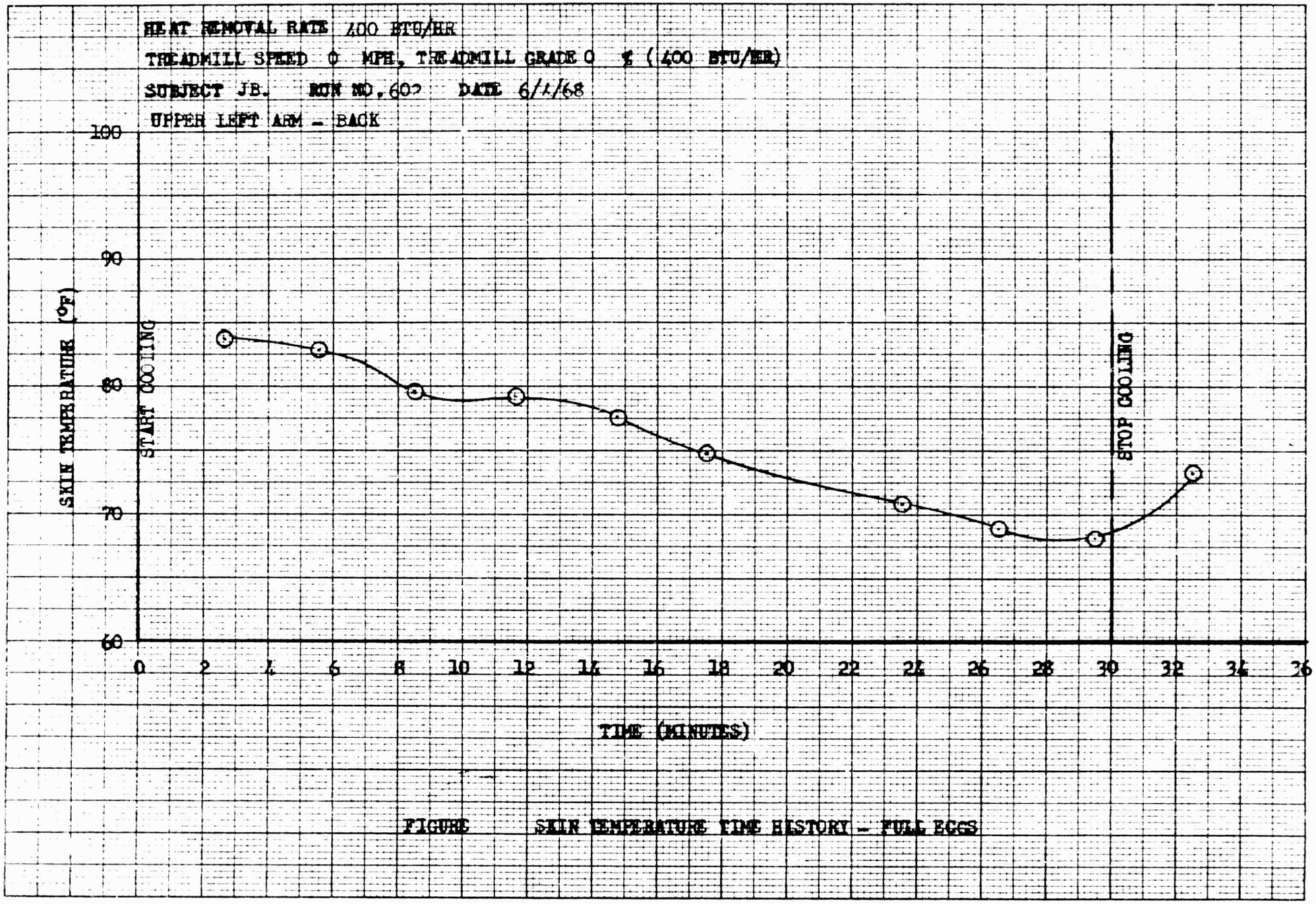


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL EGGS

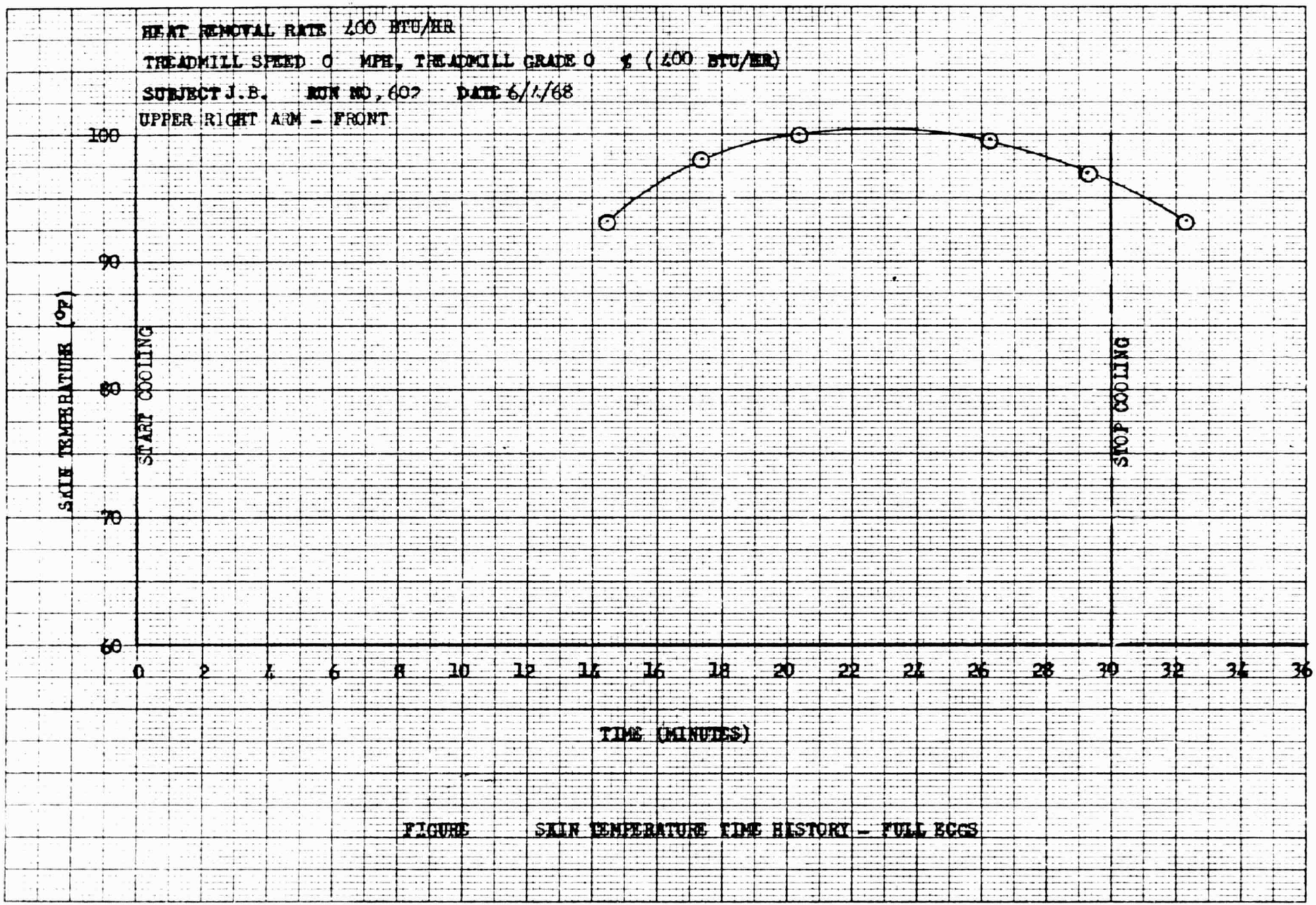


FIGURE SKIN TEMPERATURE TIME HISTORY – FULL EGGS

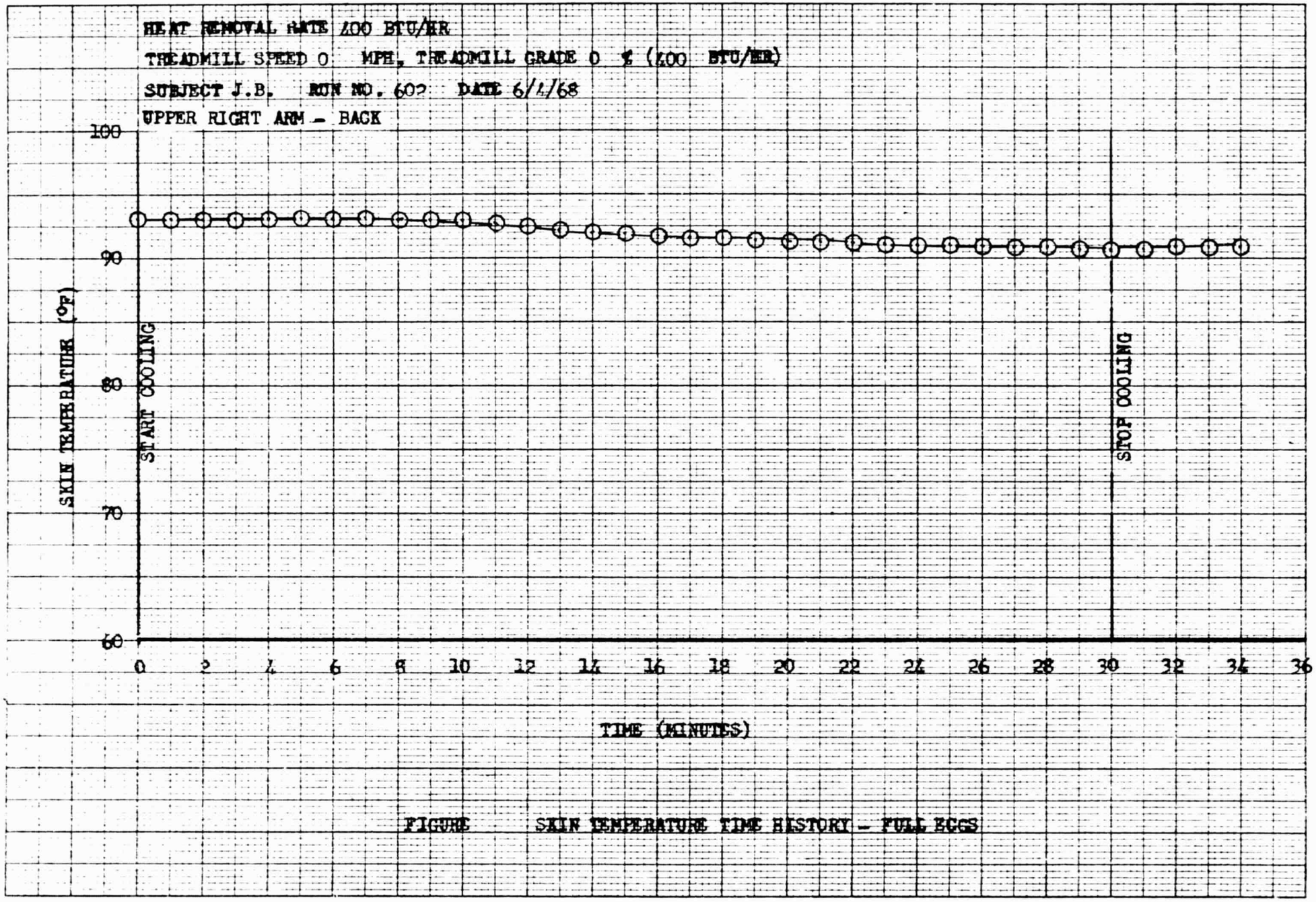


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

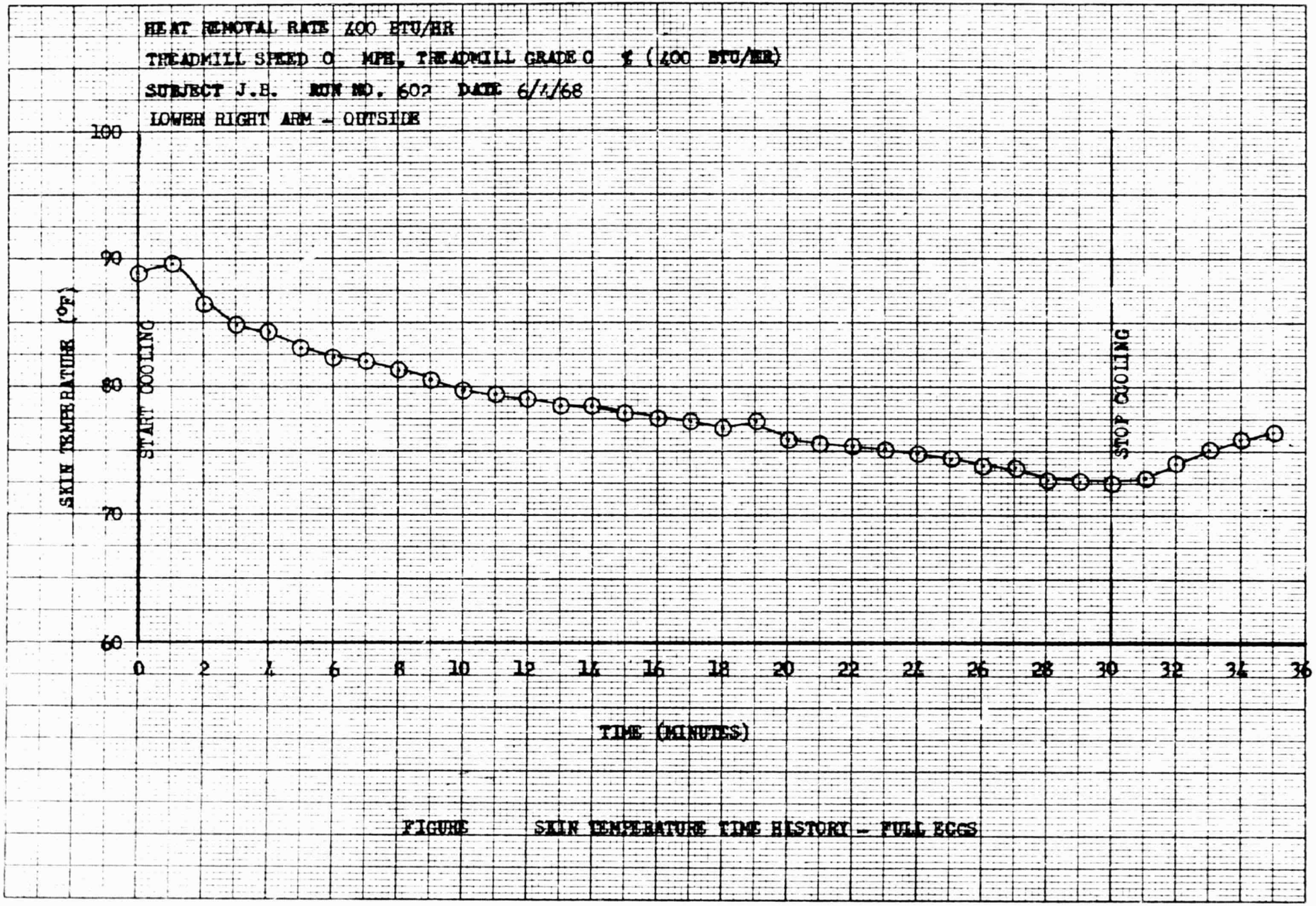


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL EGGS

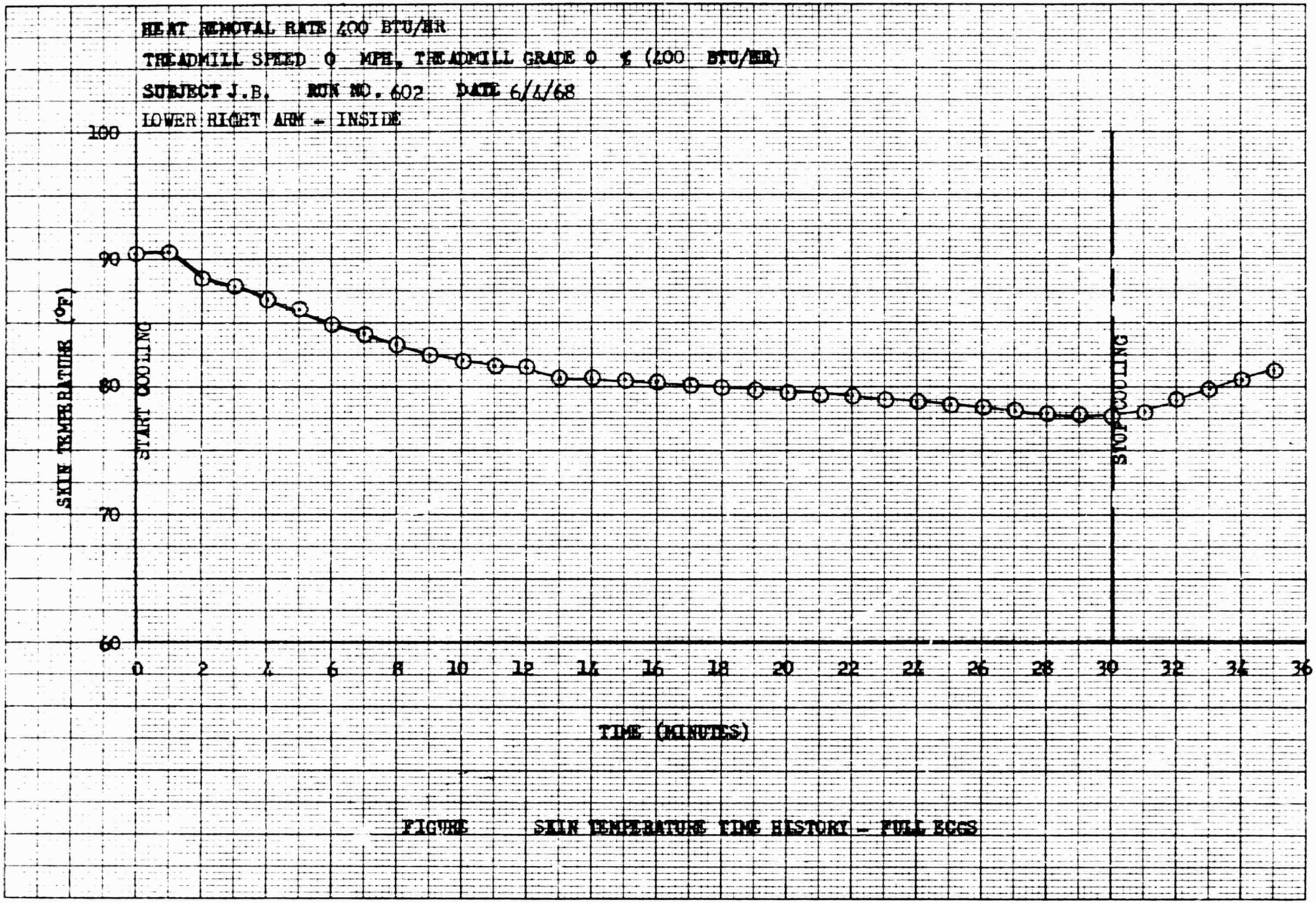


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

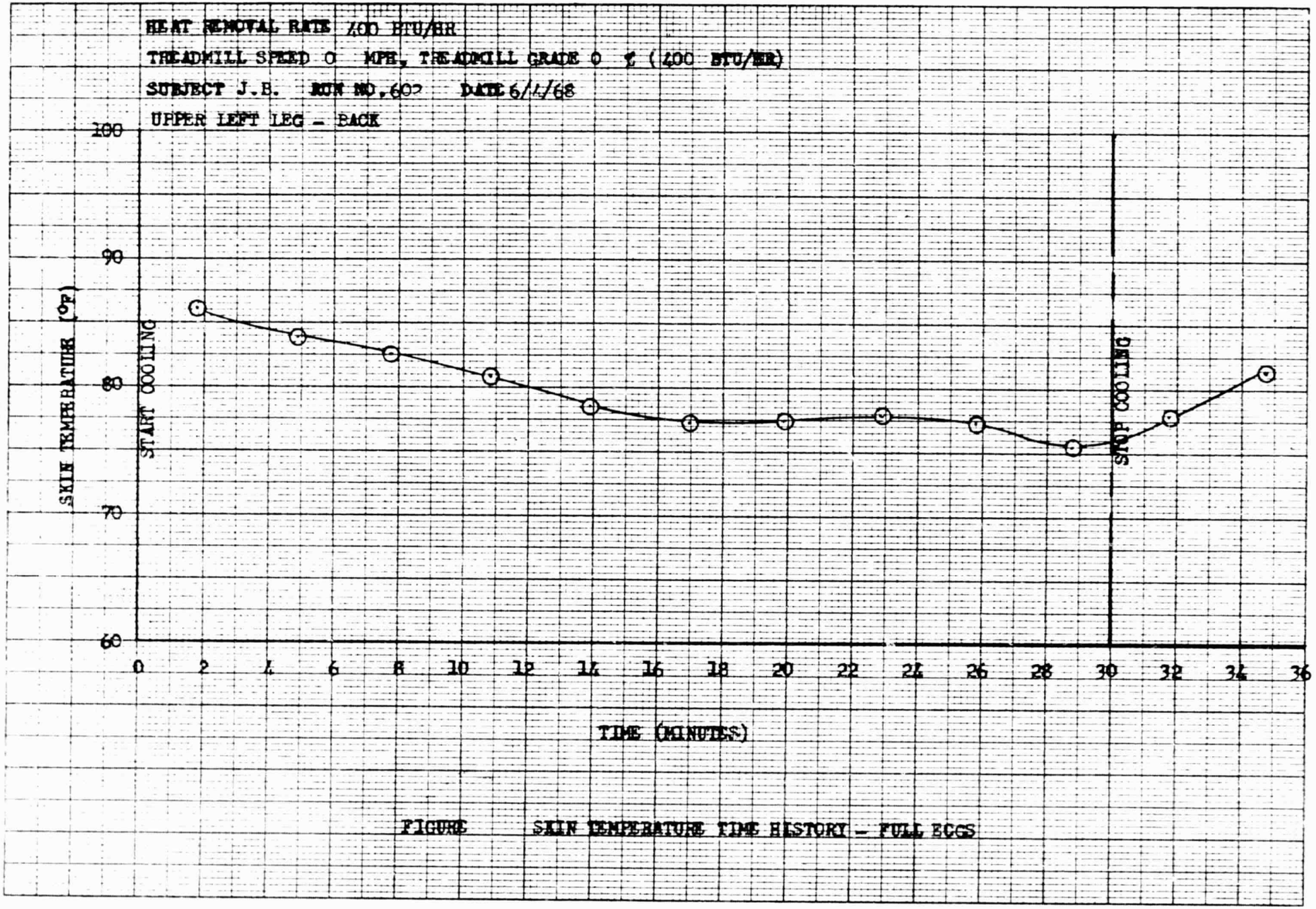


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

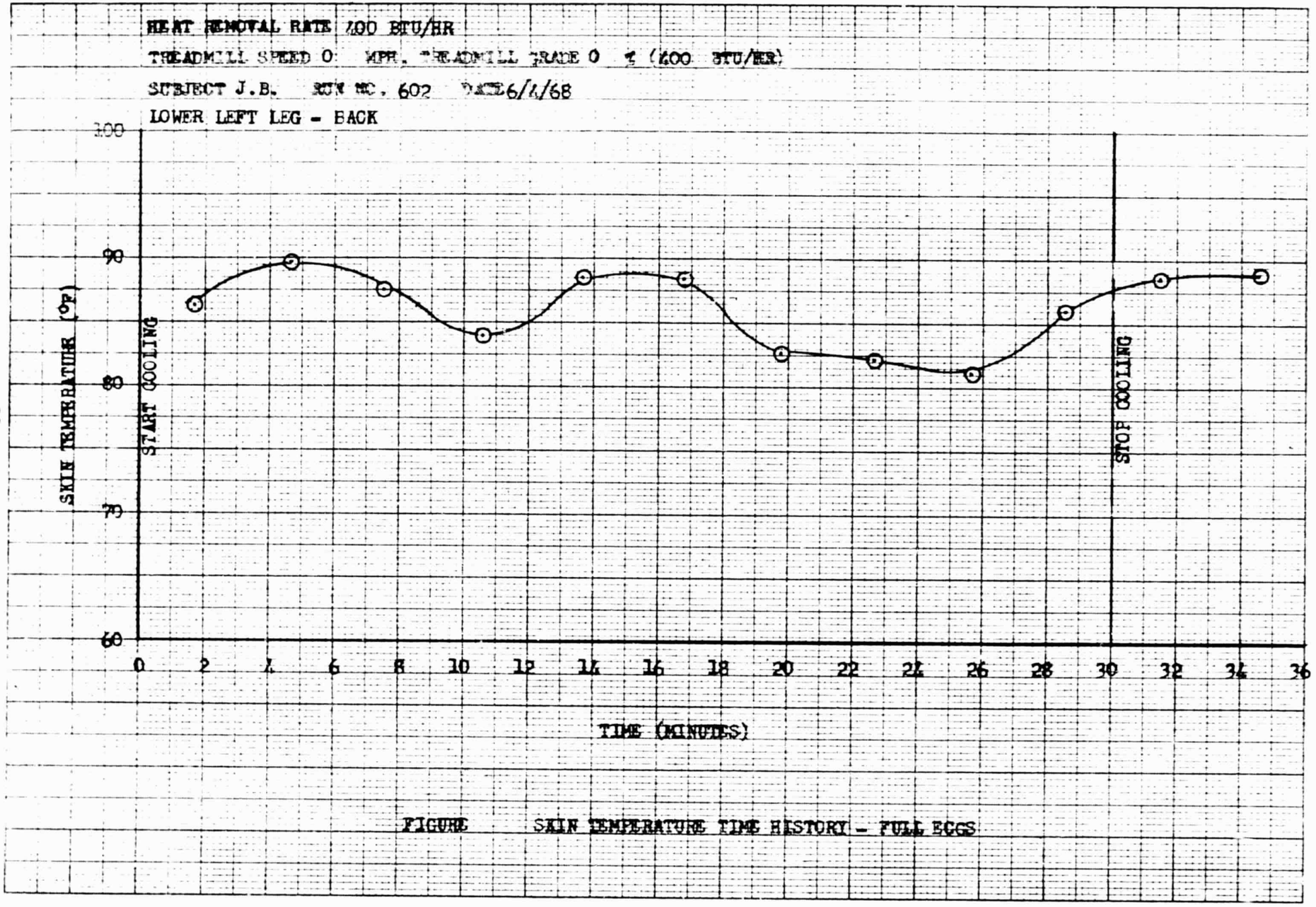


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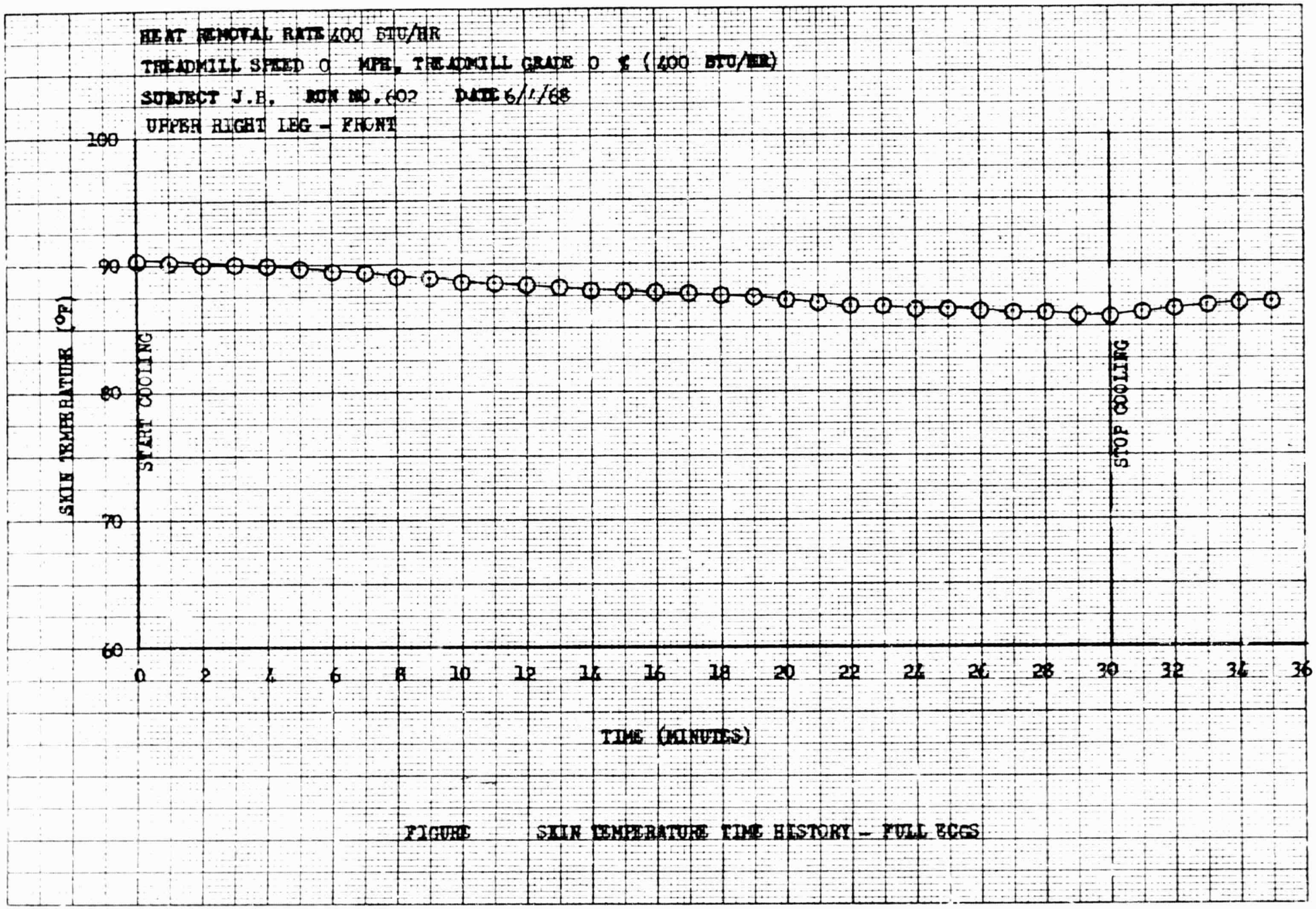


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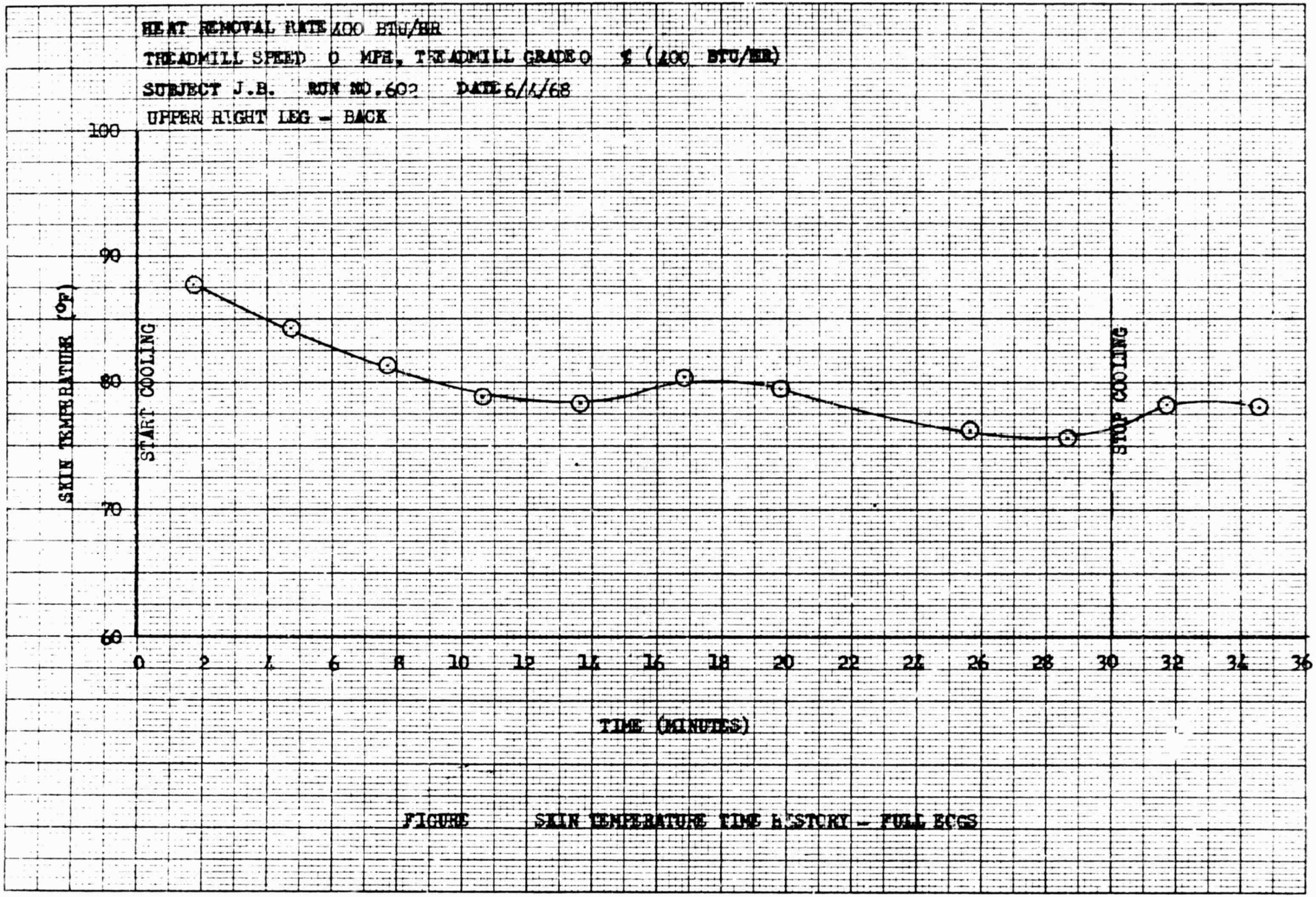


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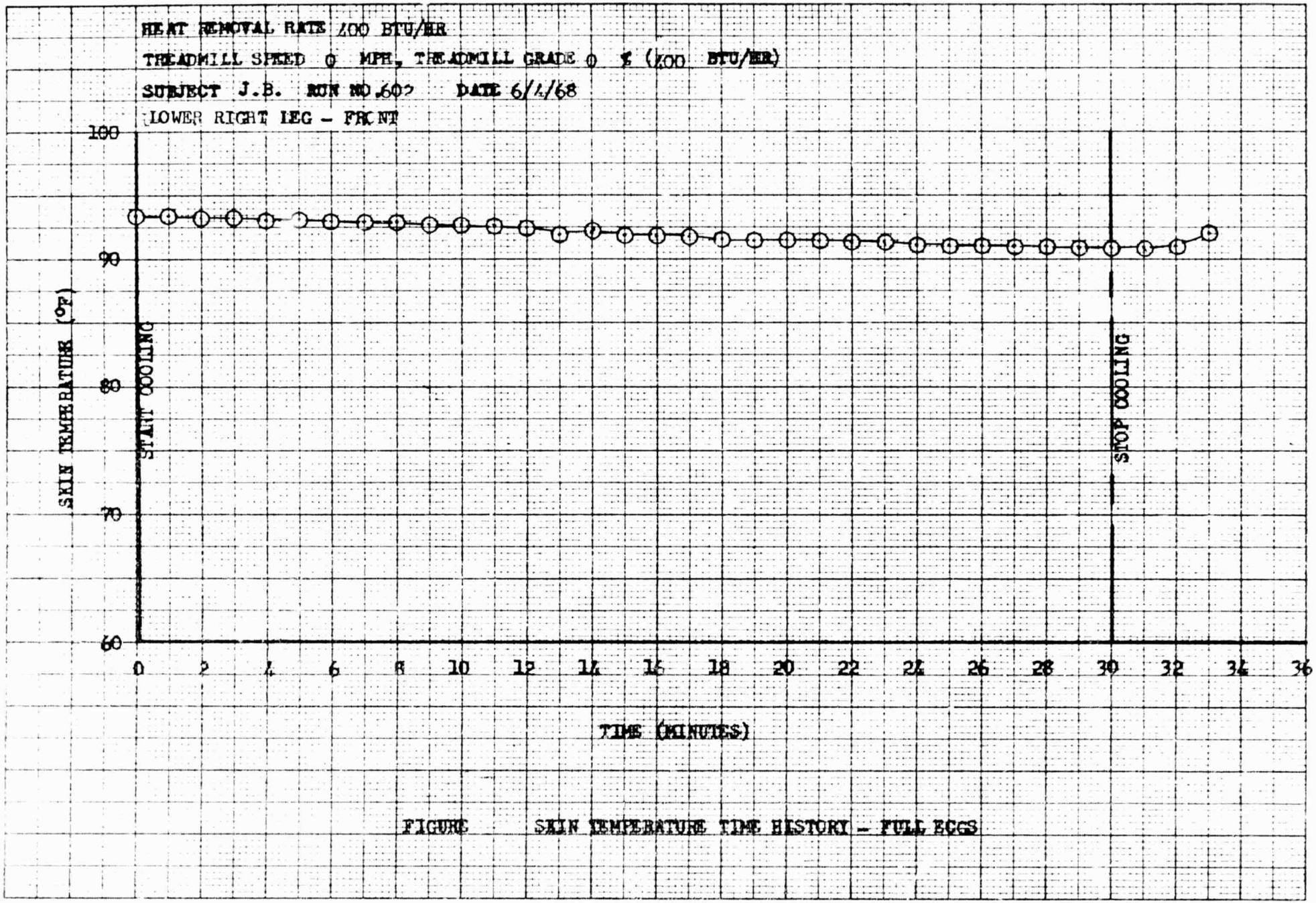


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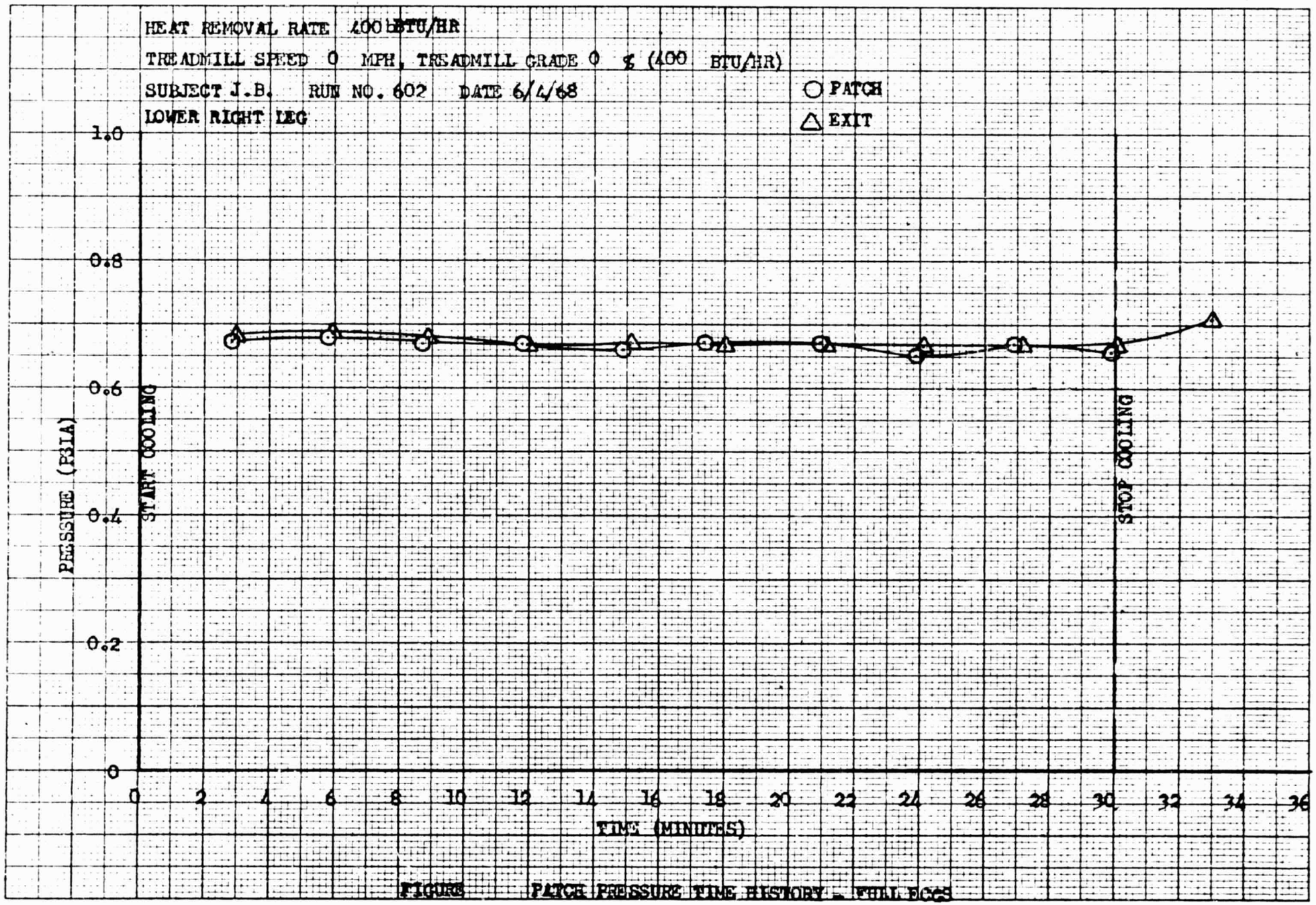


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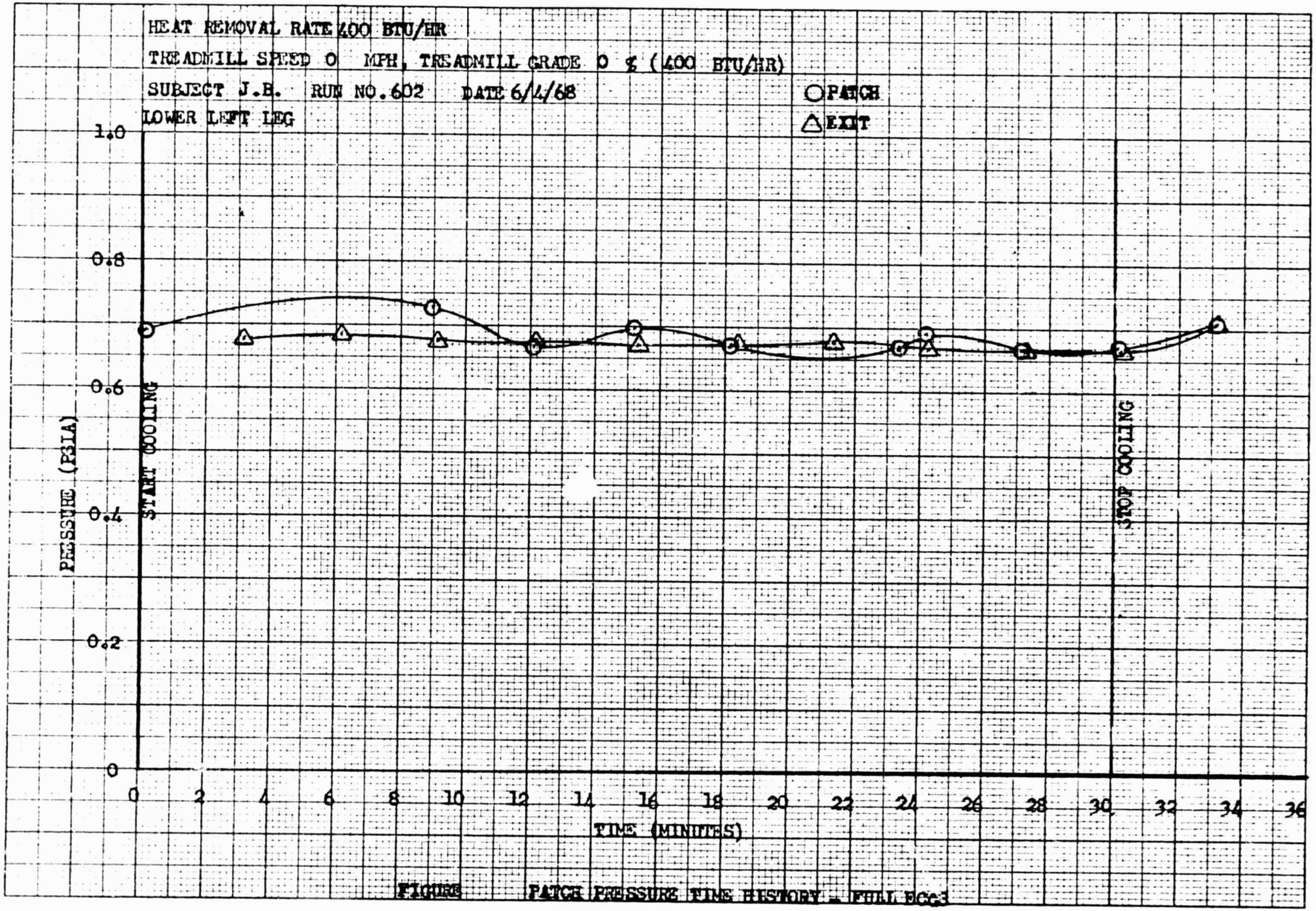


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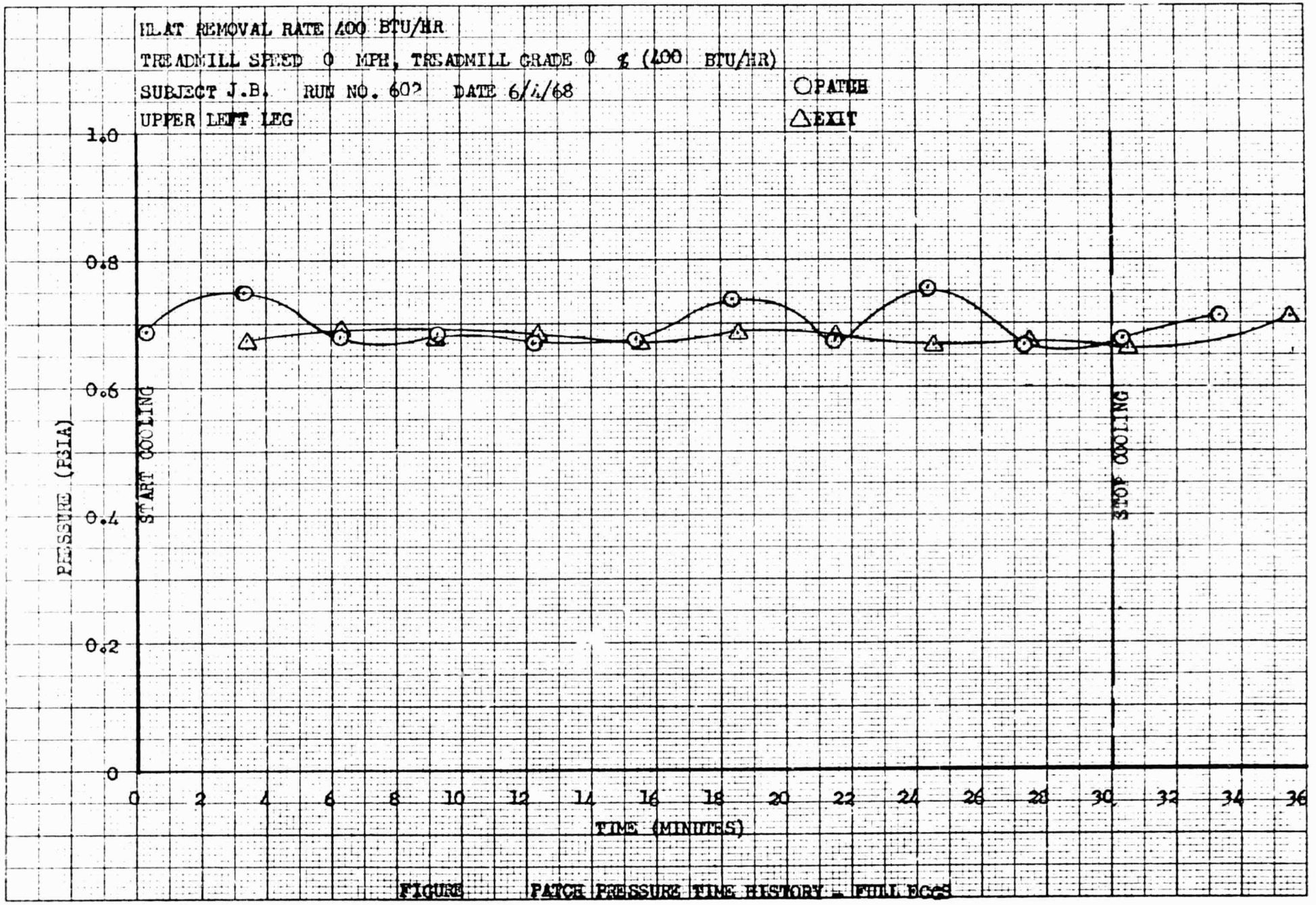


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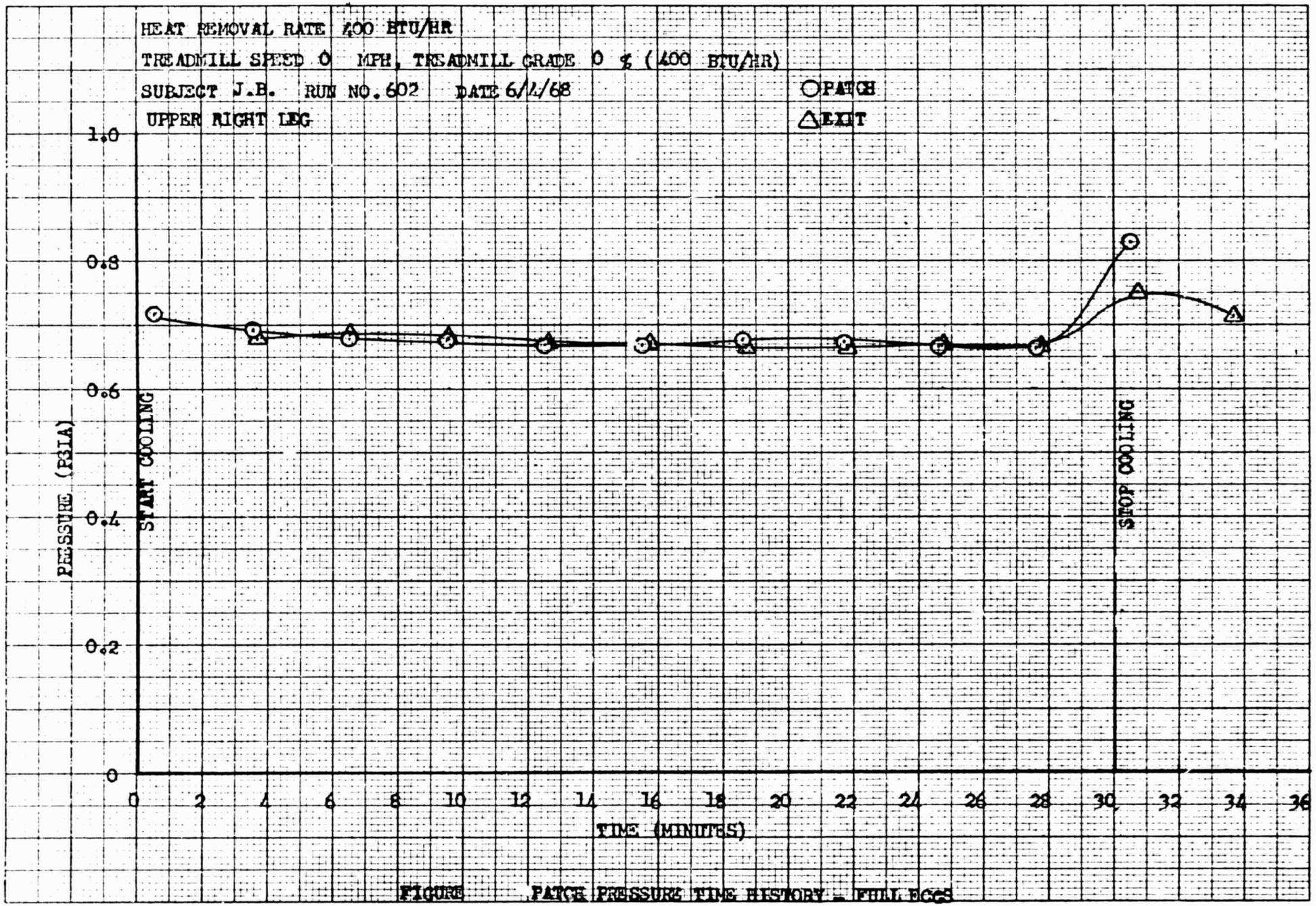


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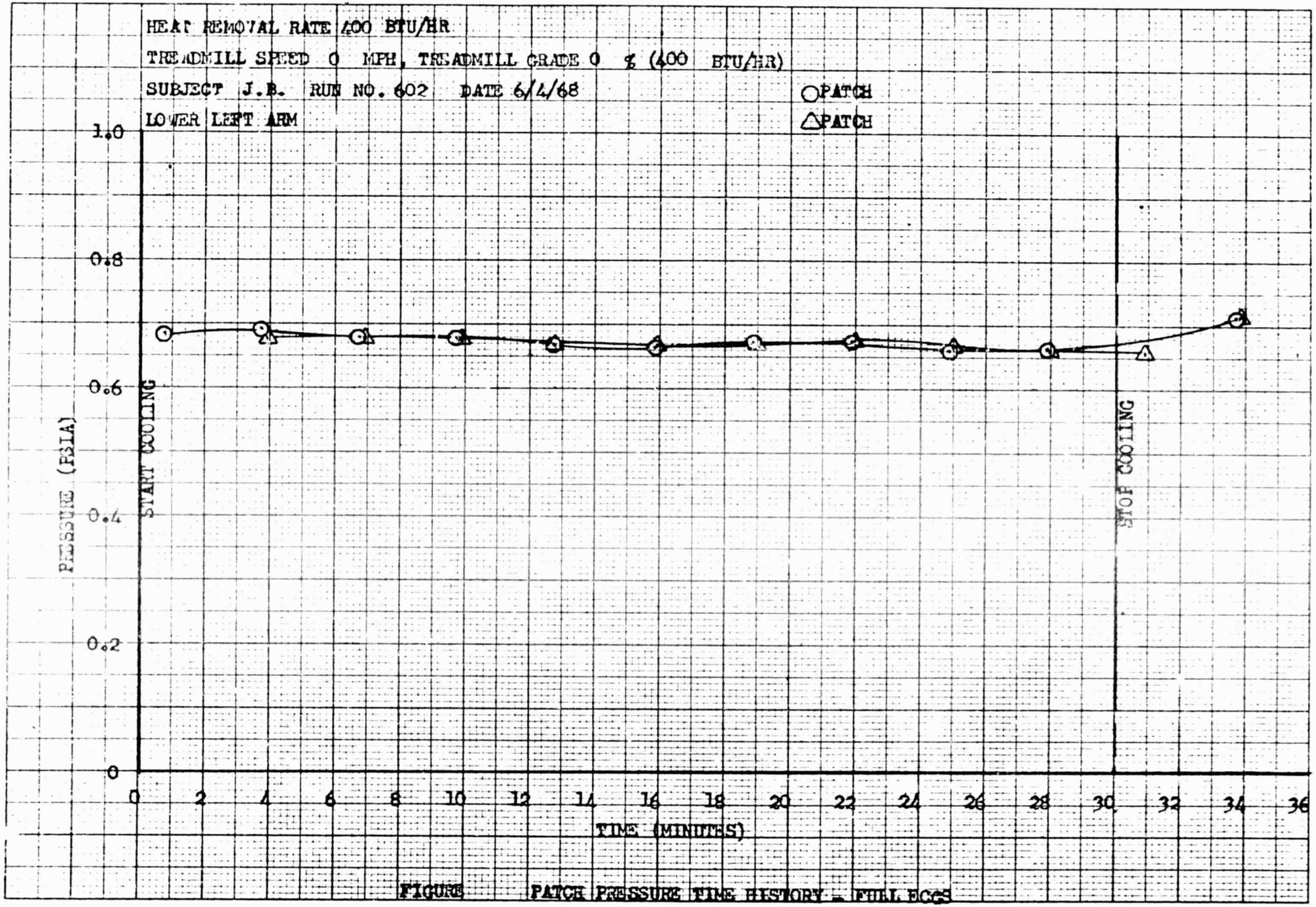


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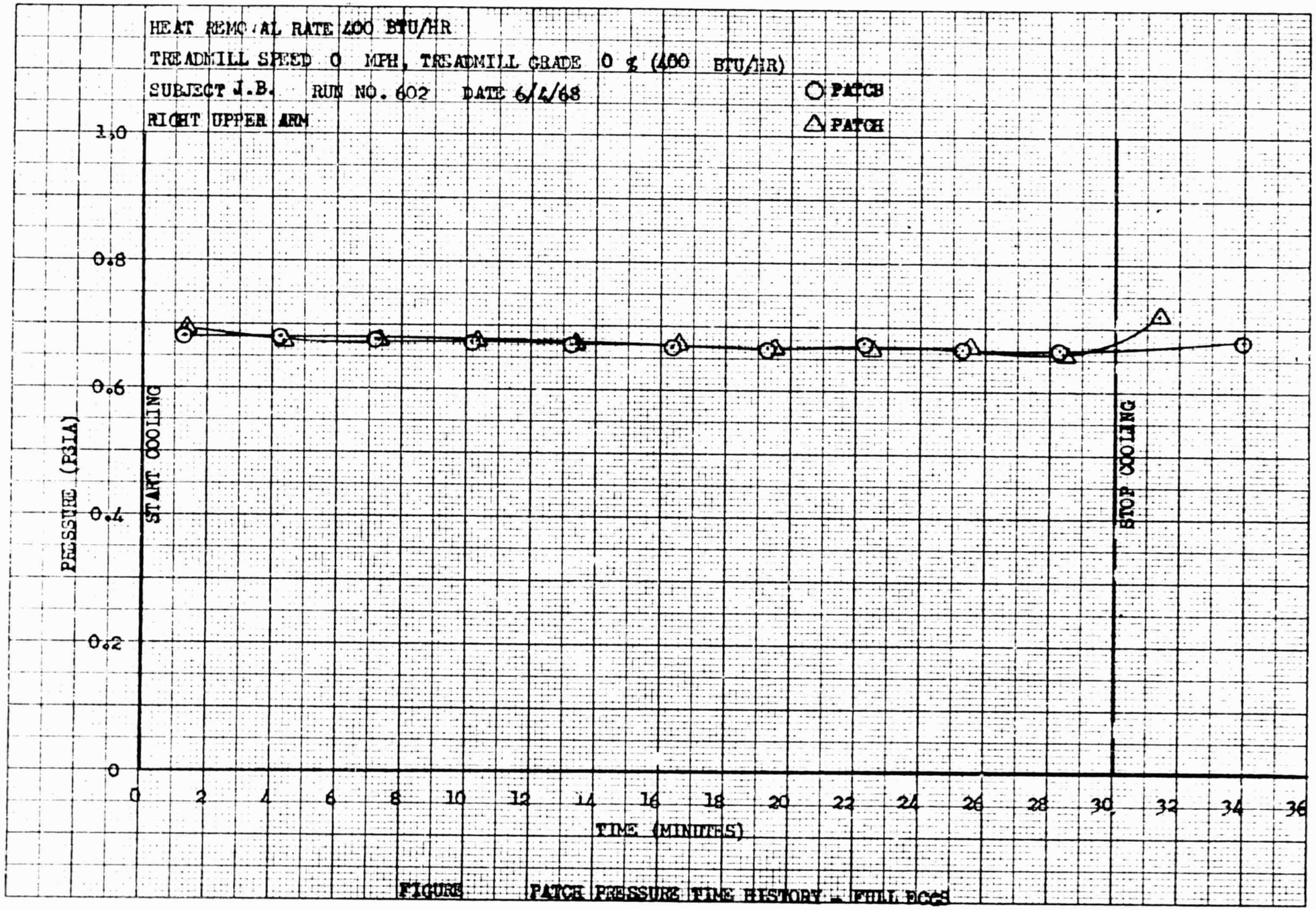


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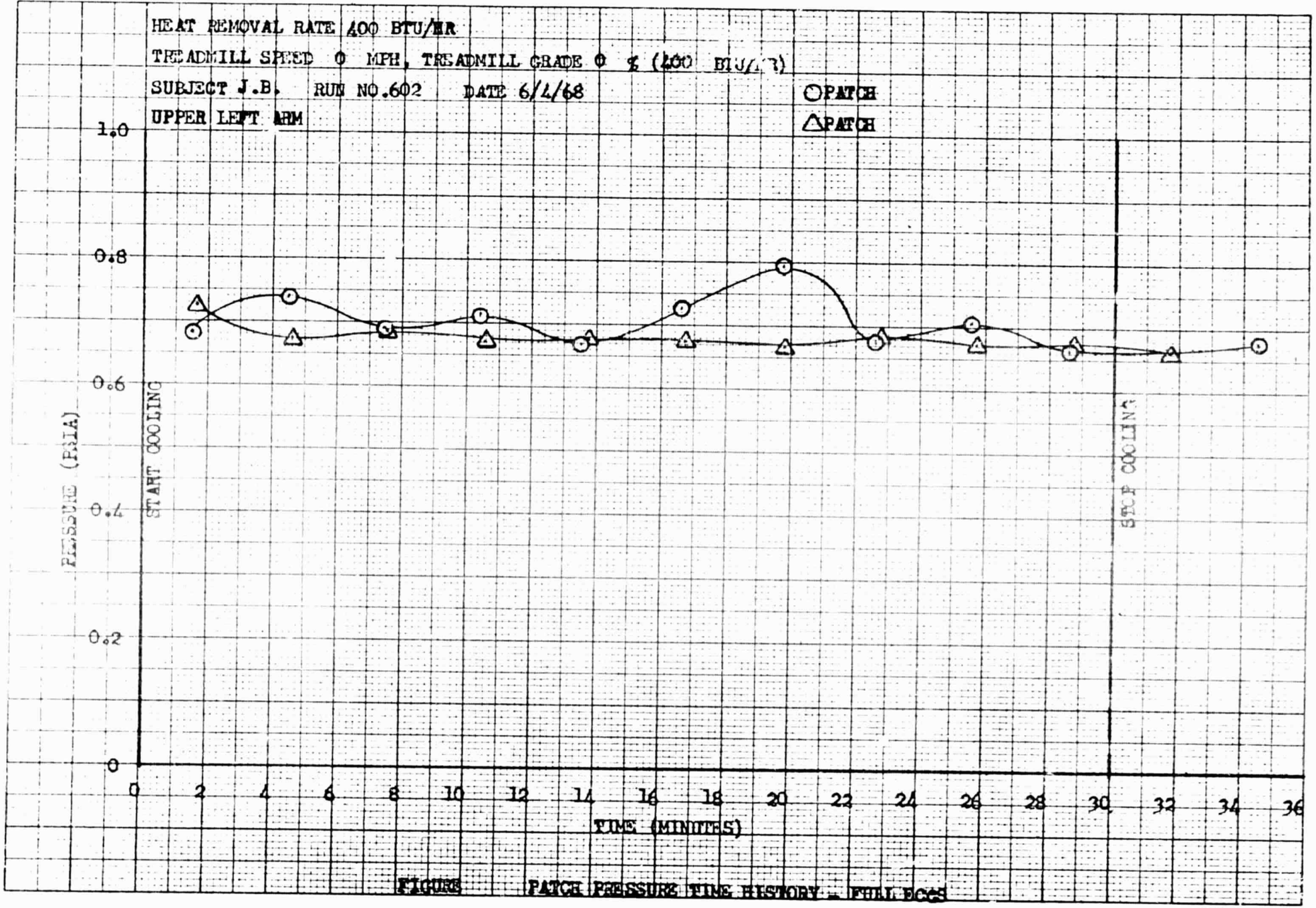


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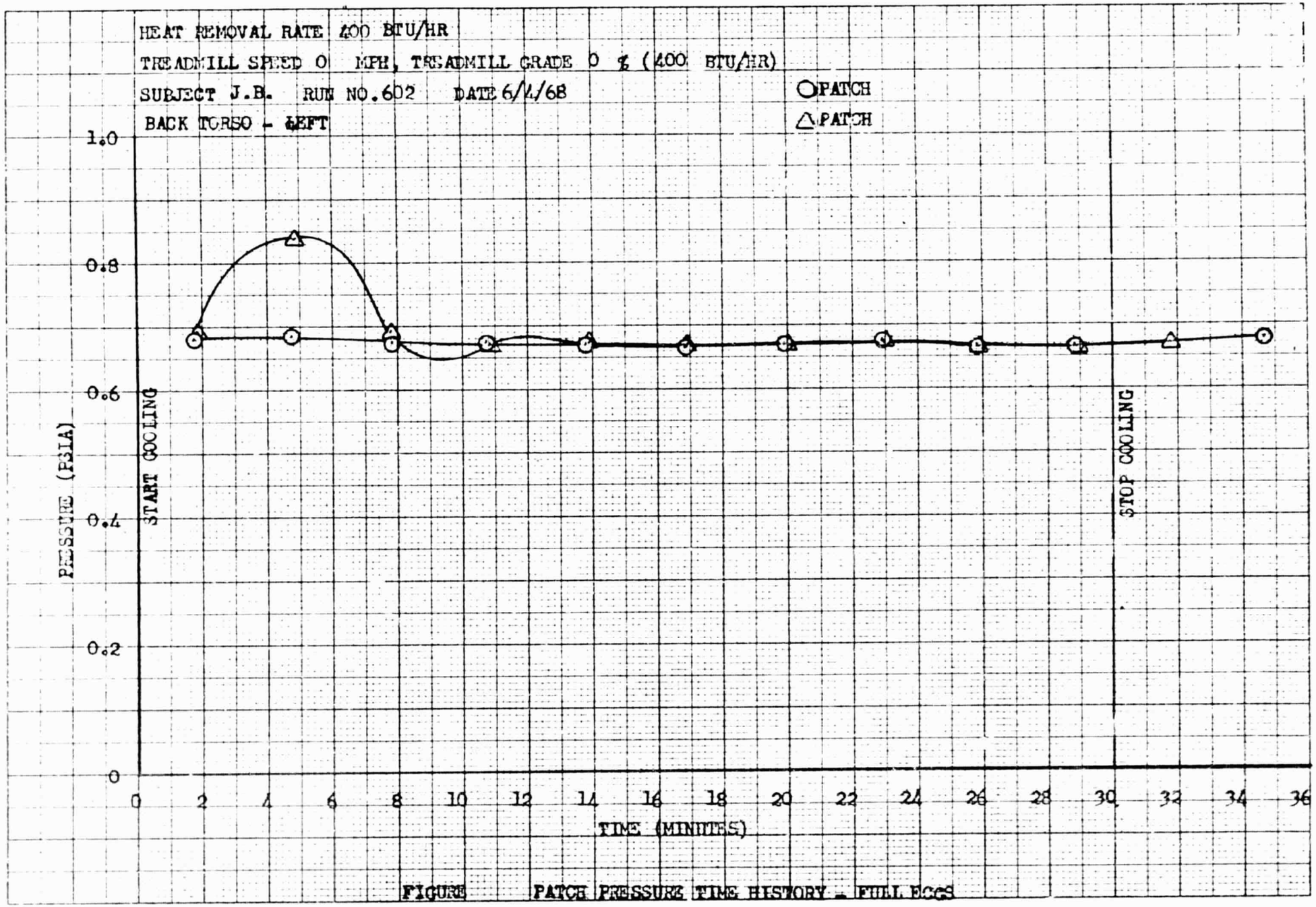


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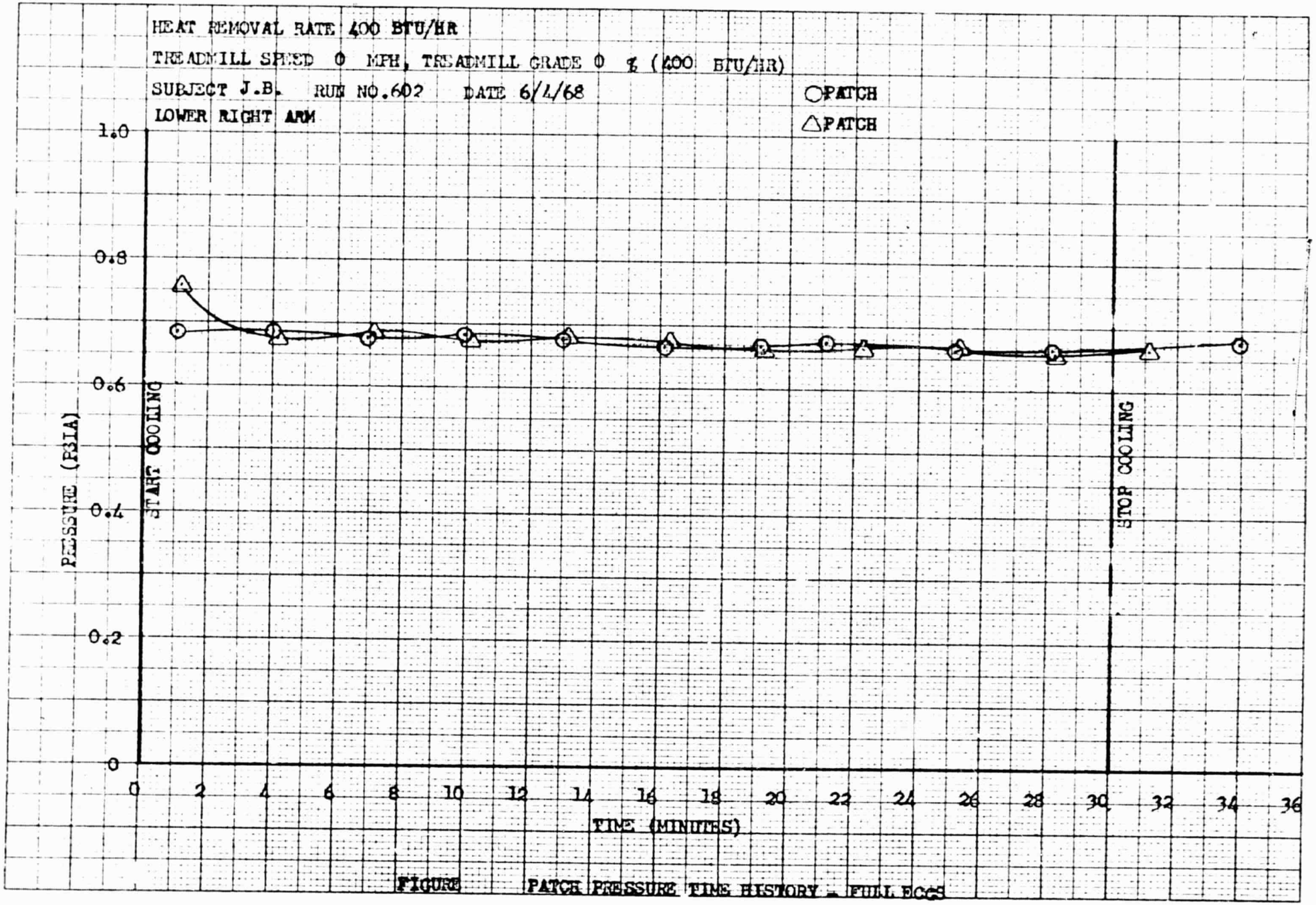


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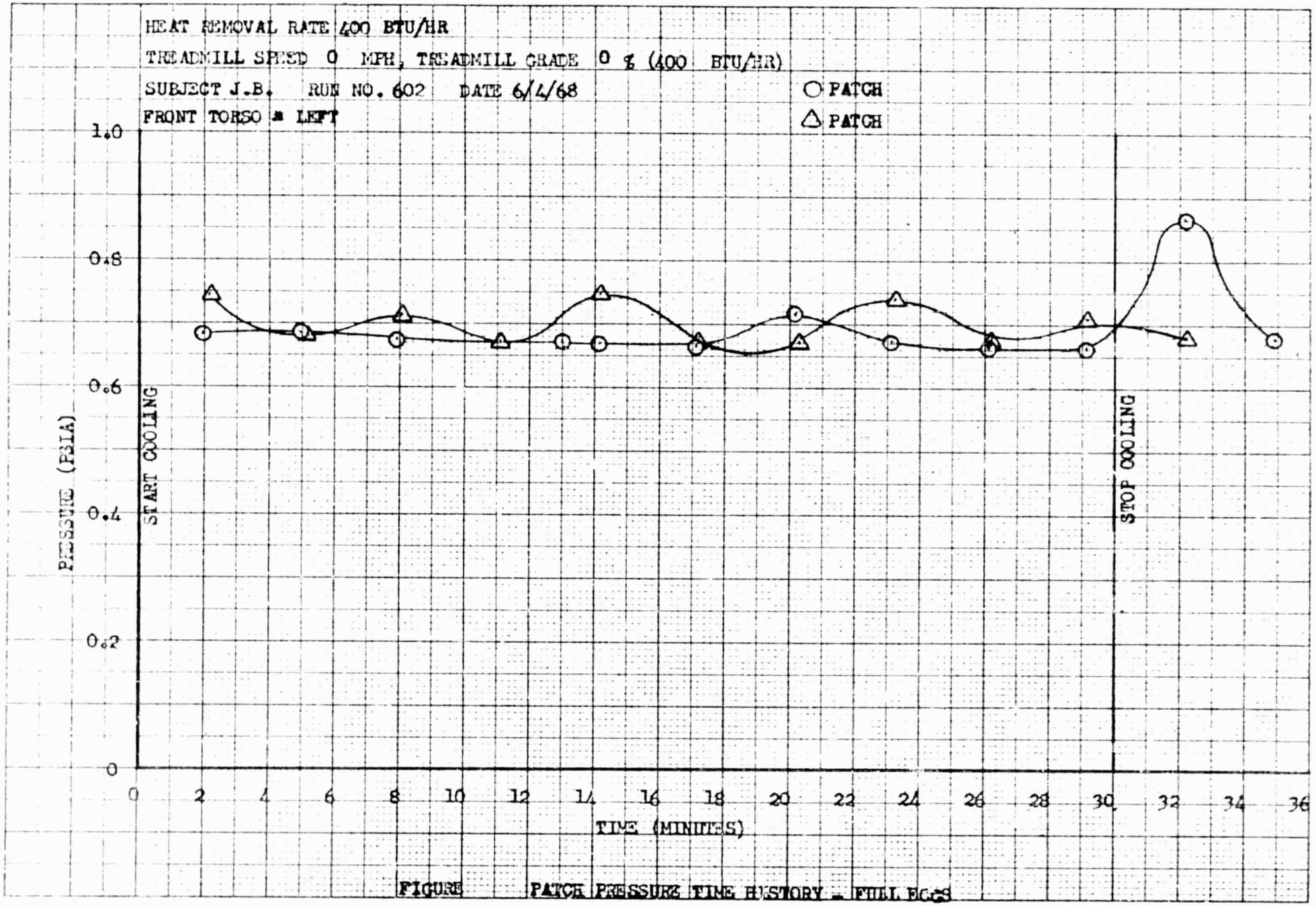


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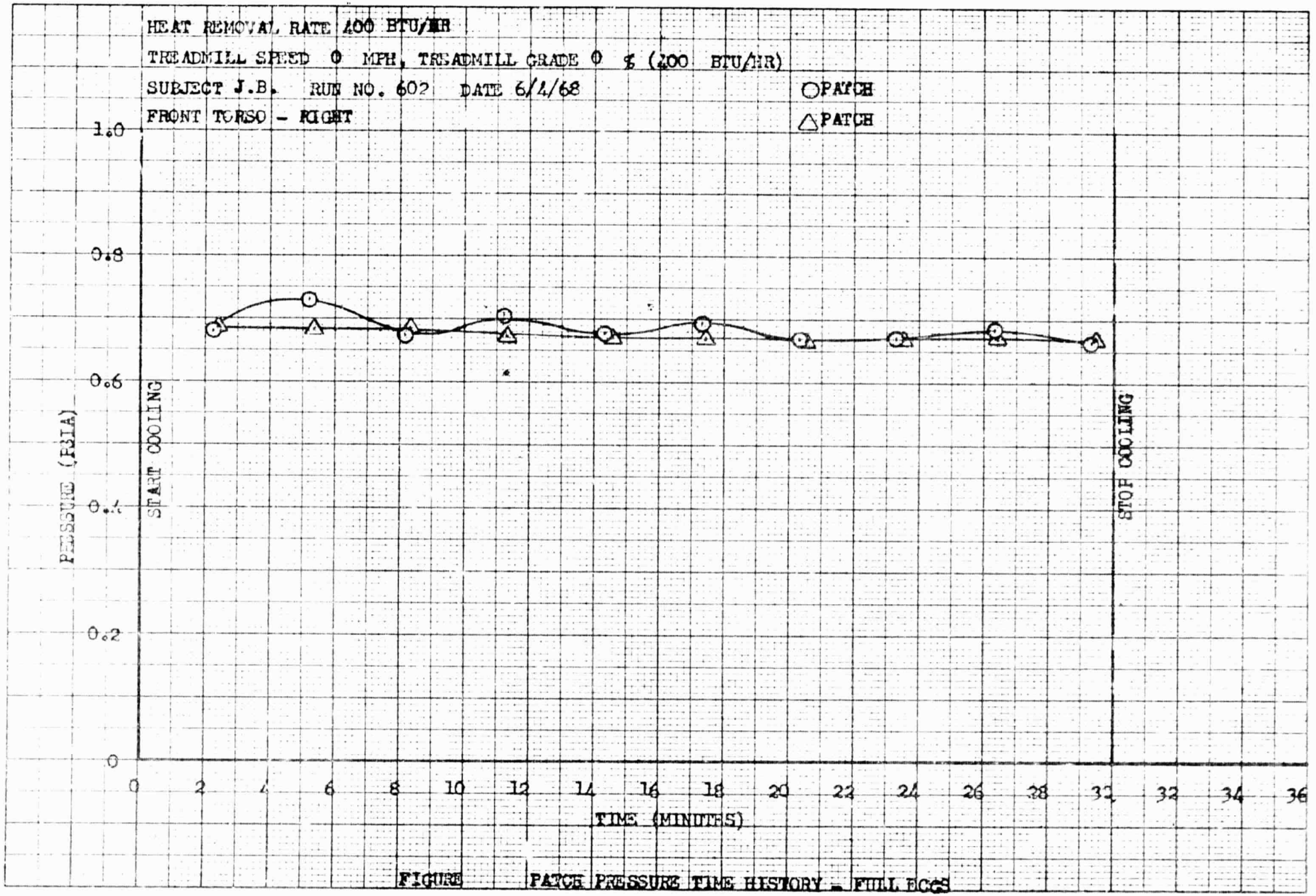


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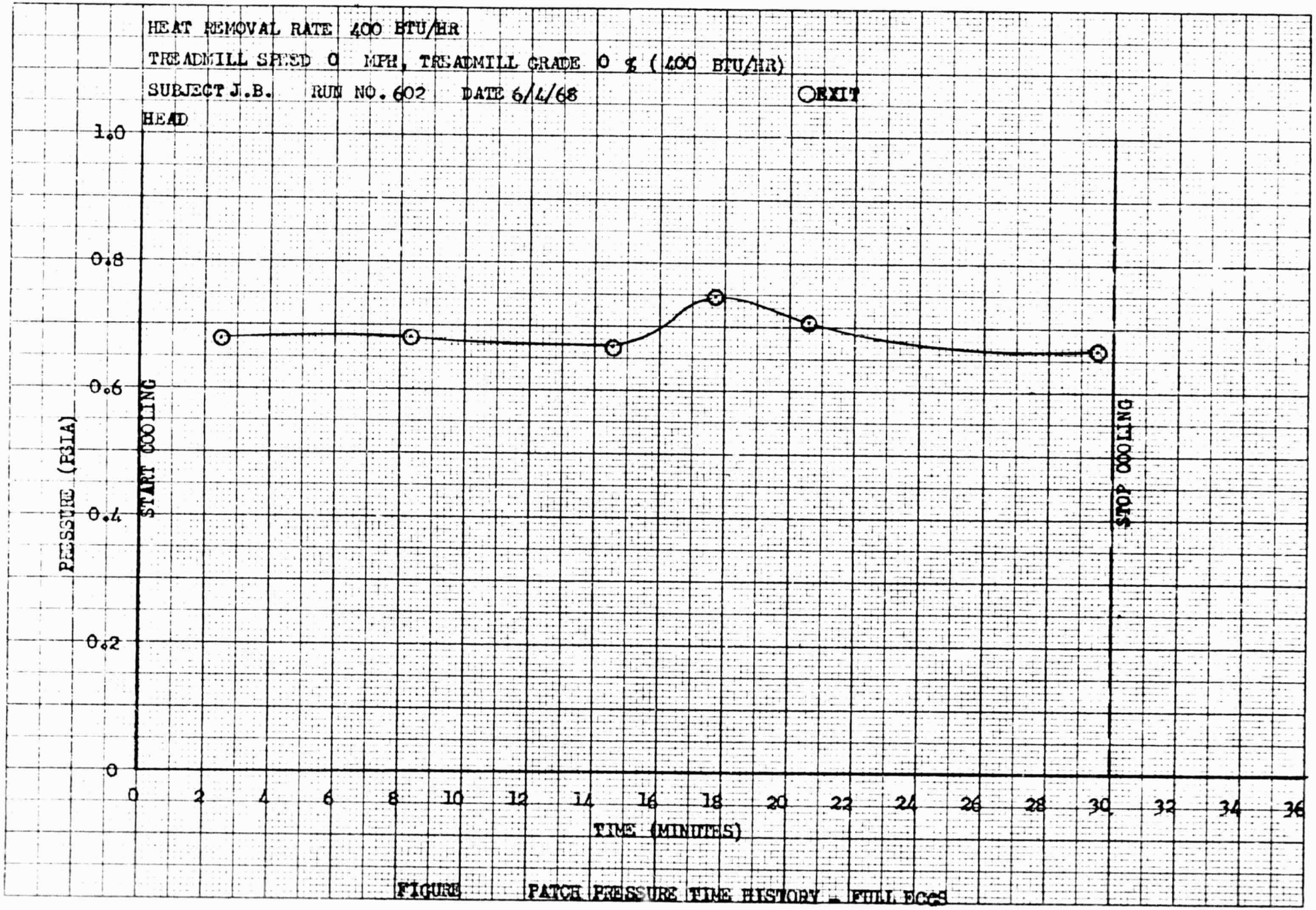


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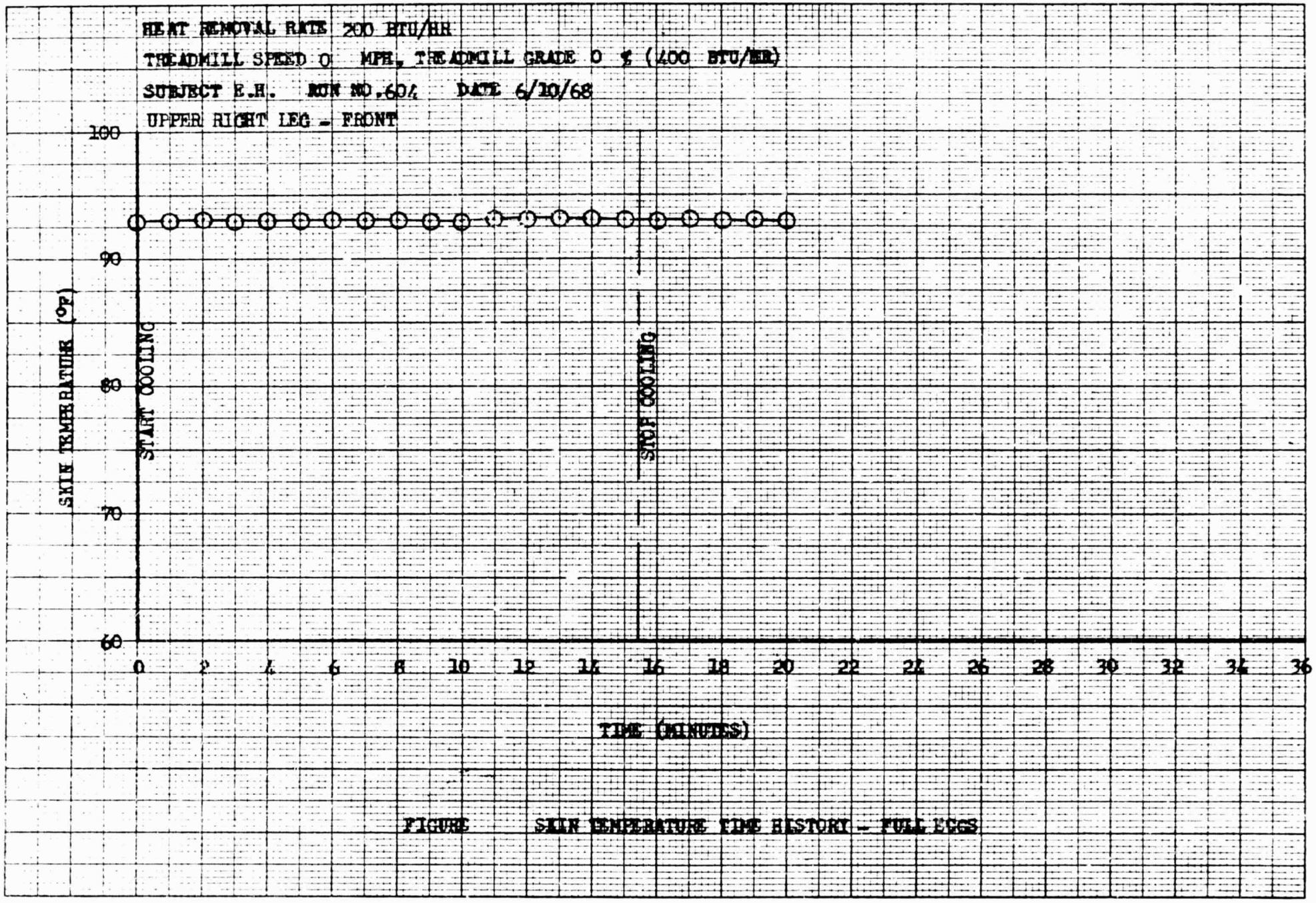


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL EGGS

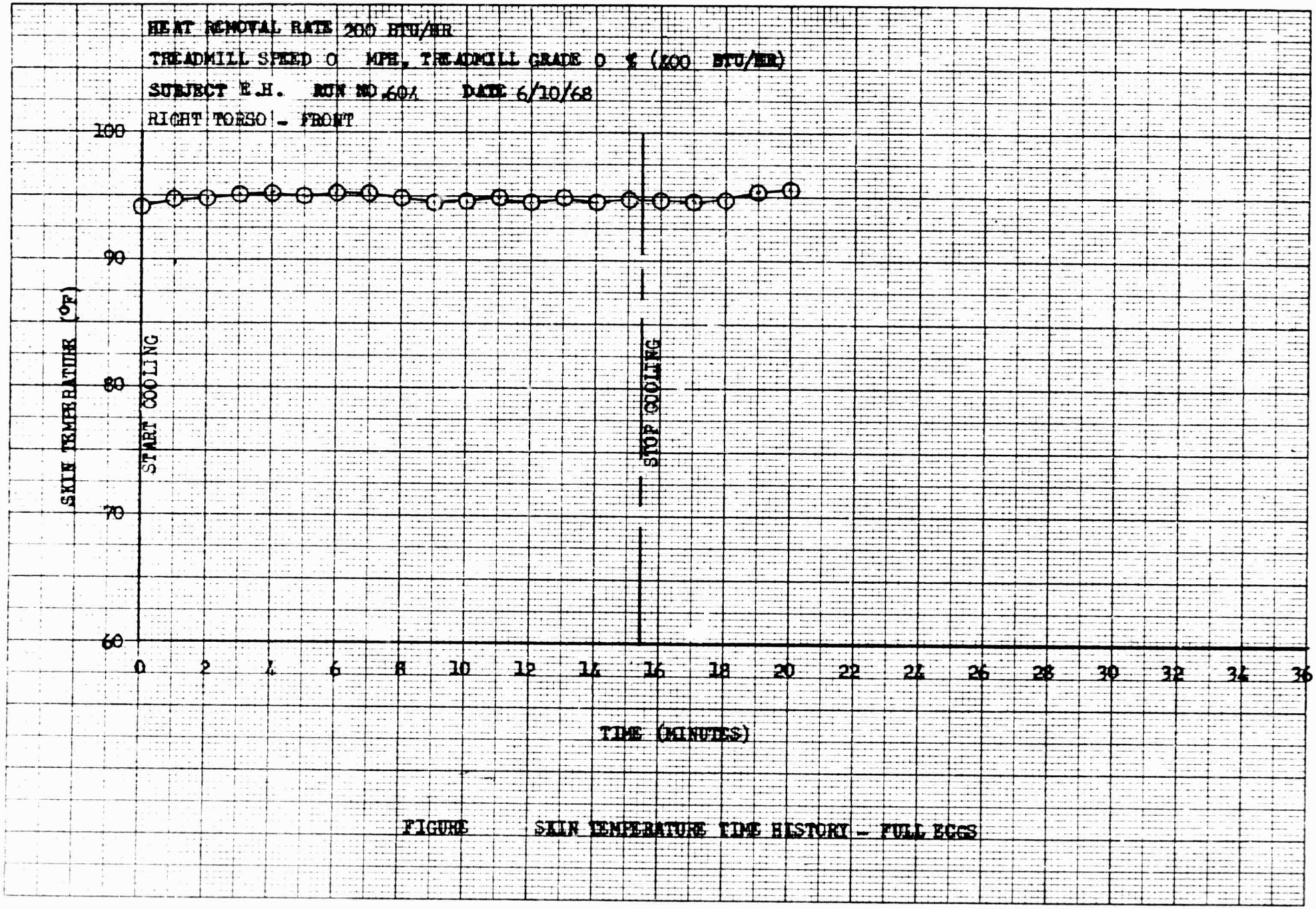


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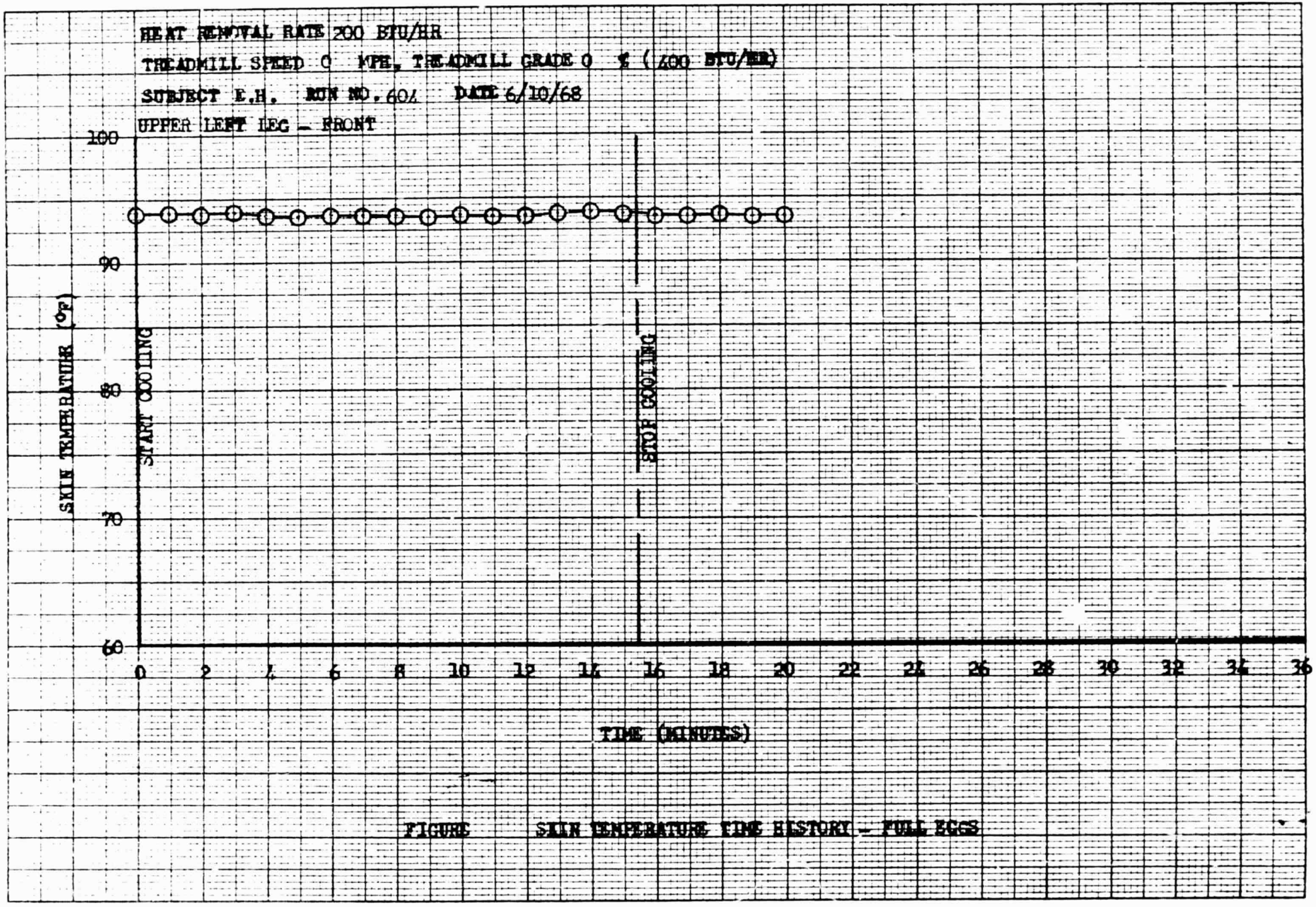


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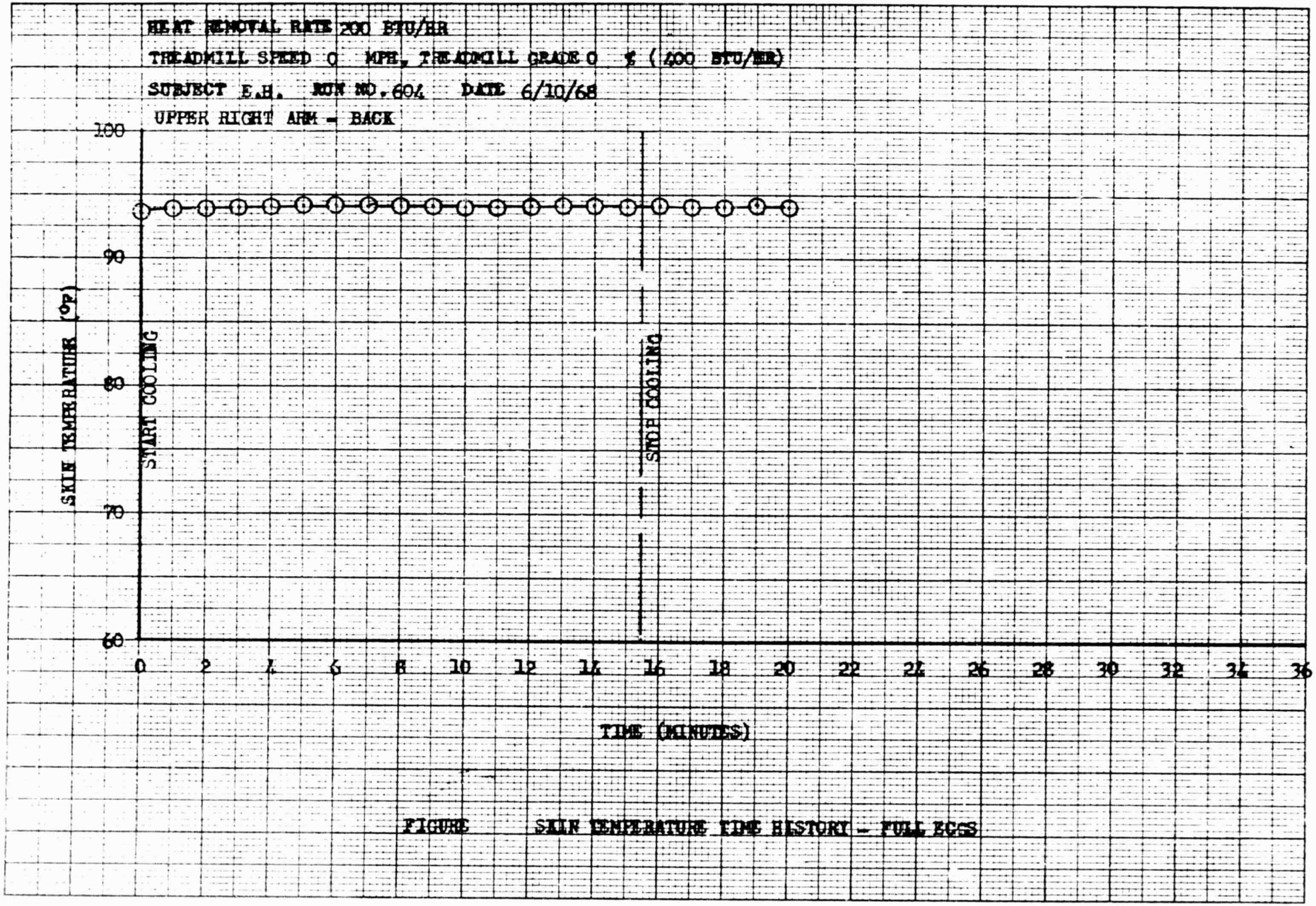


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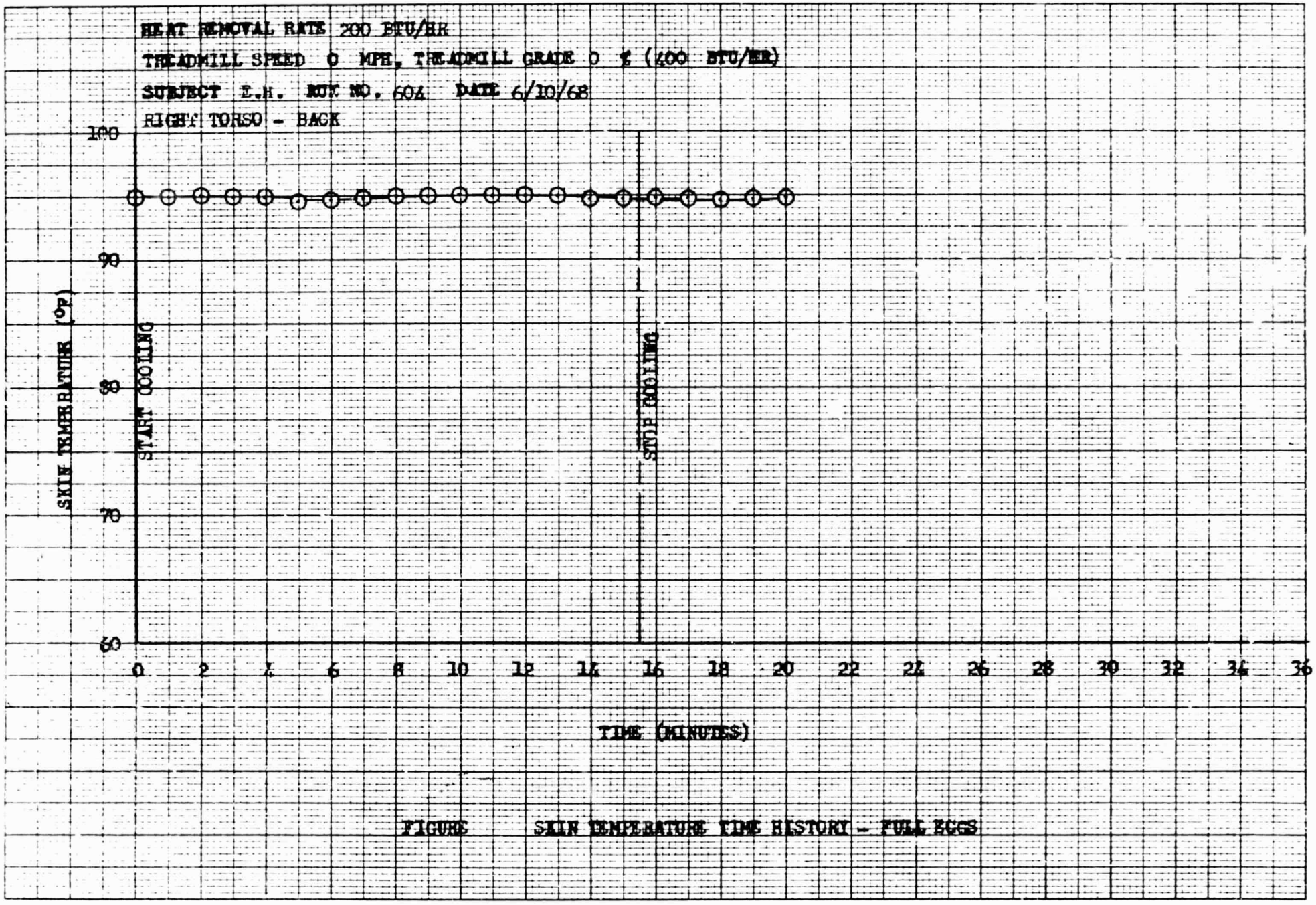


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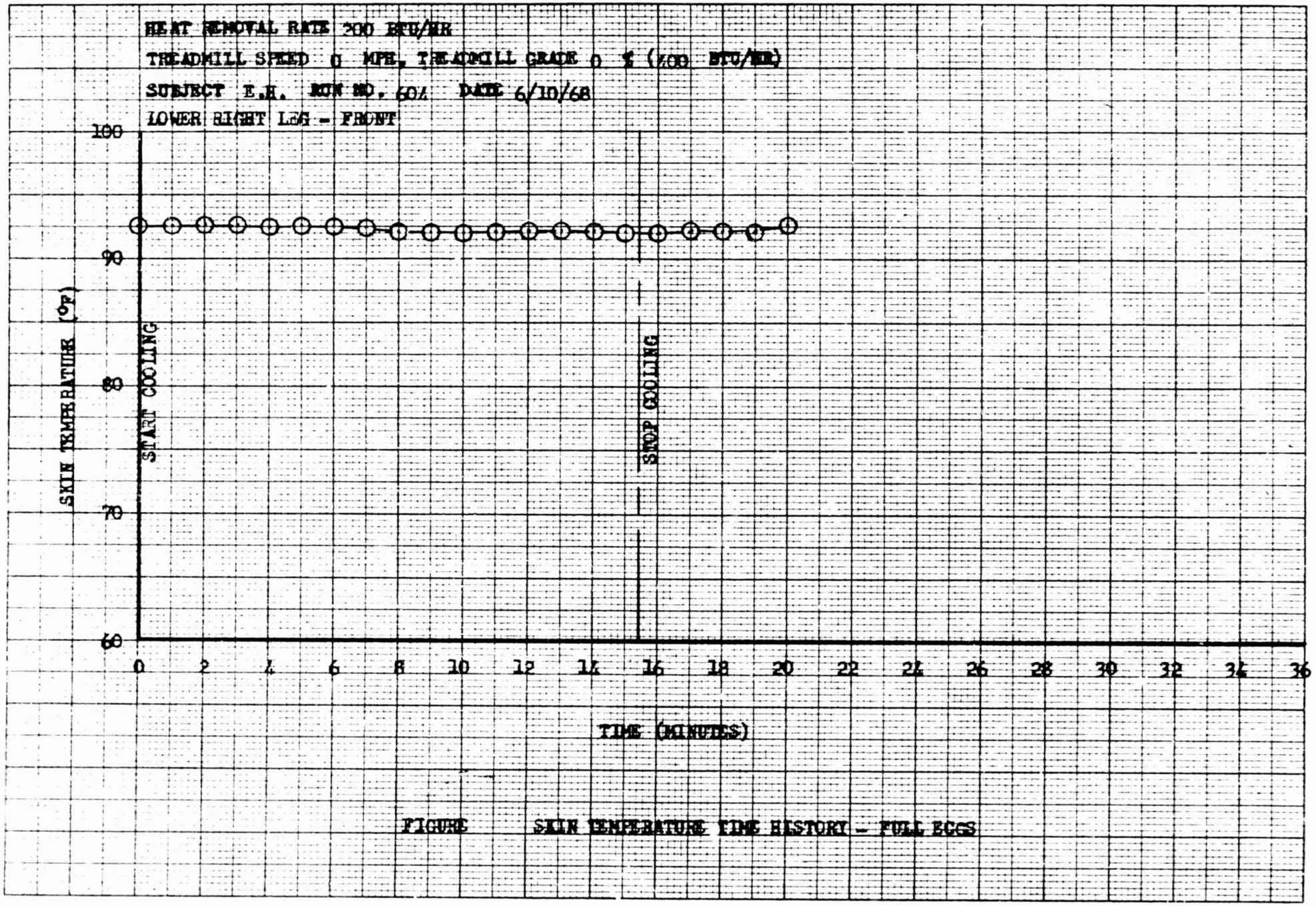


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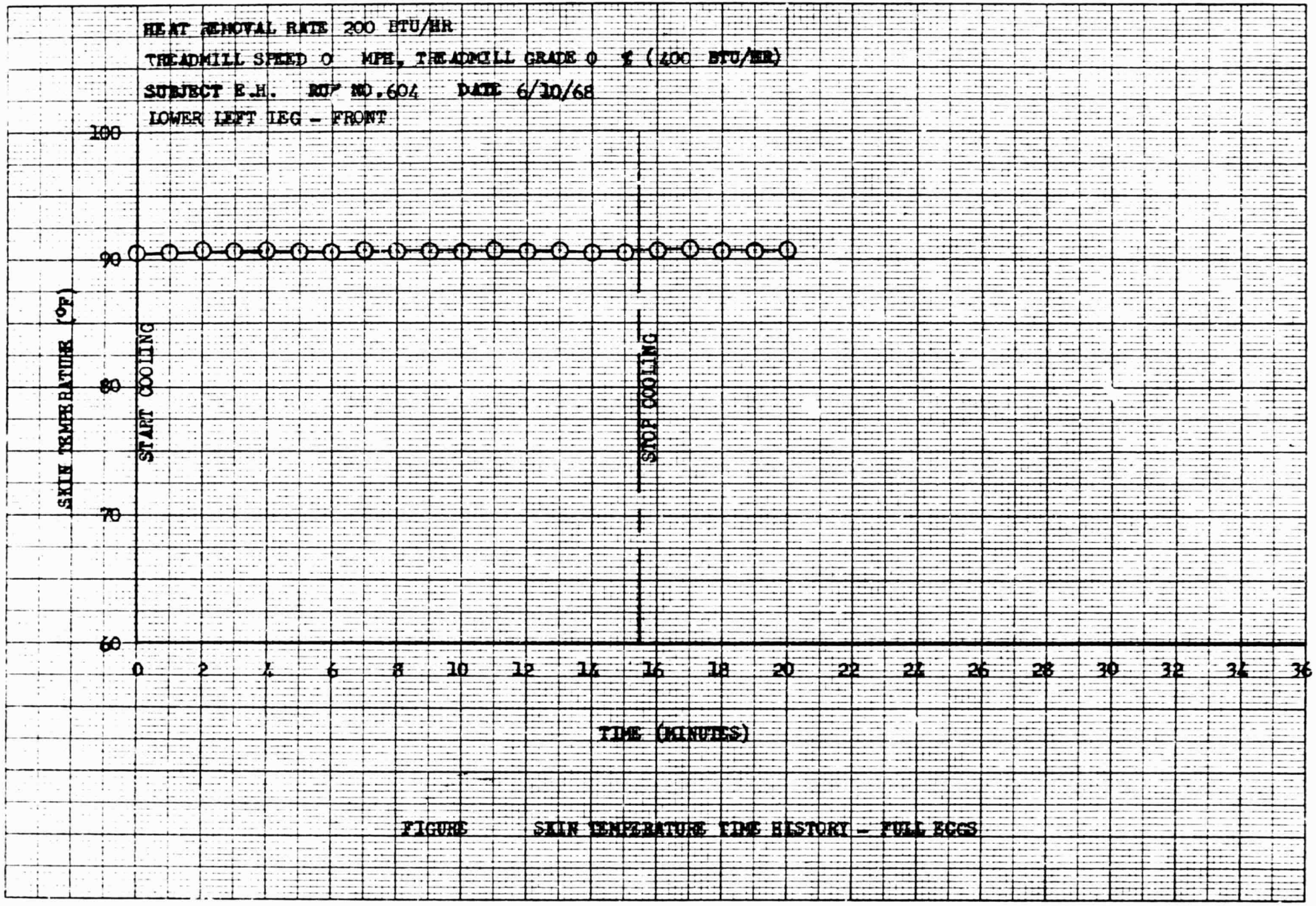


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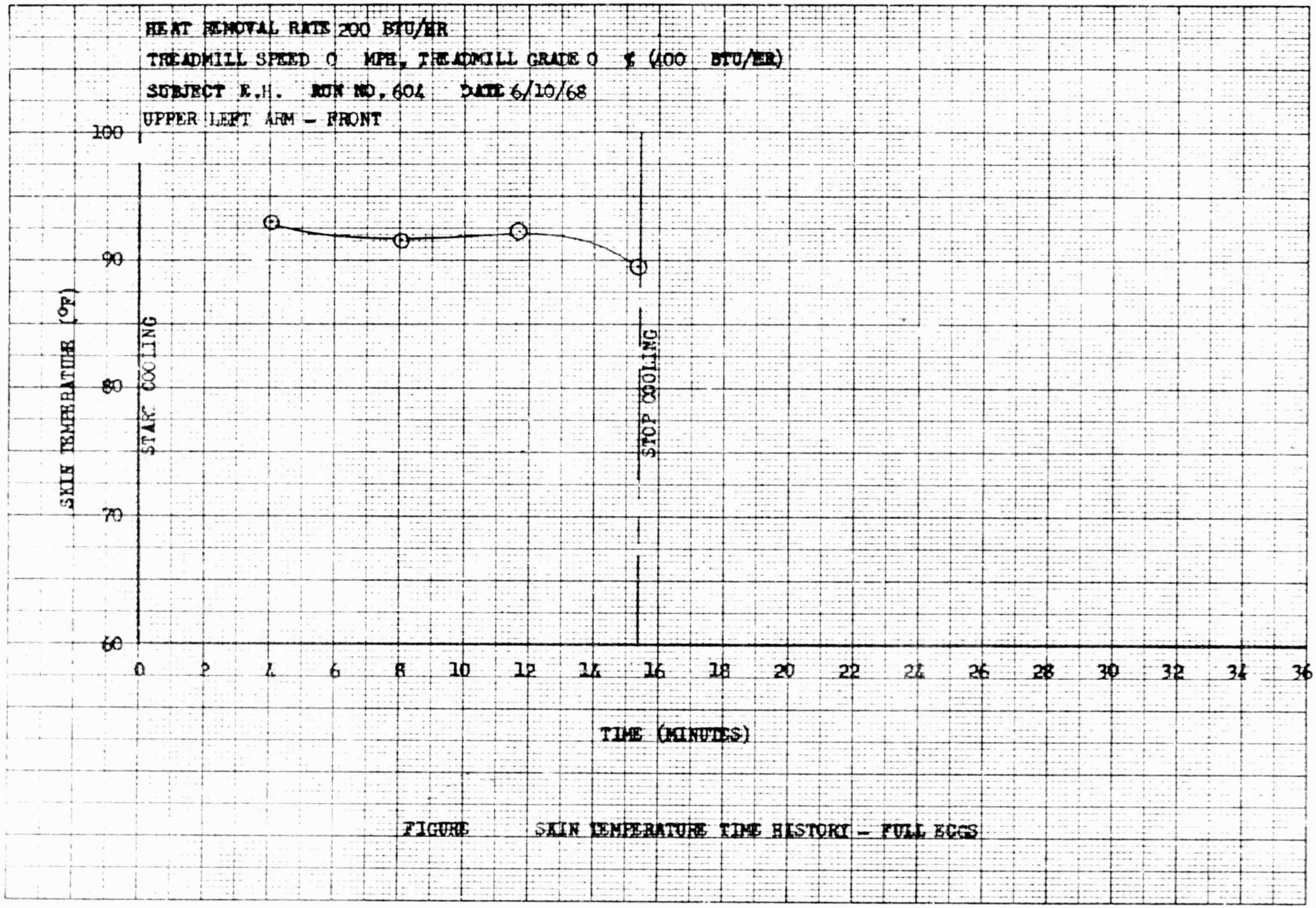


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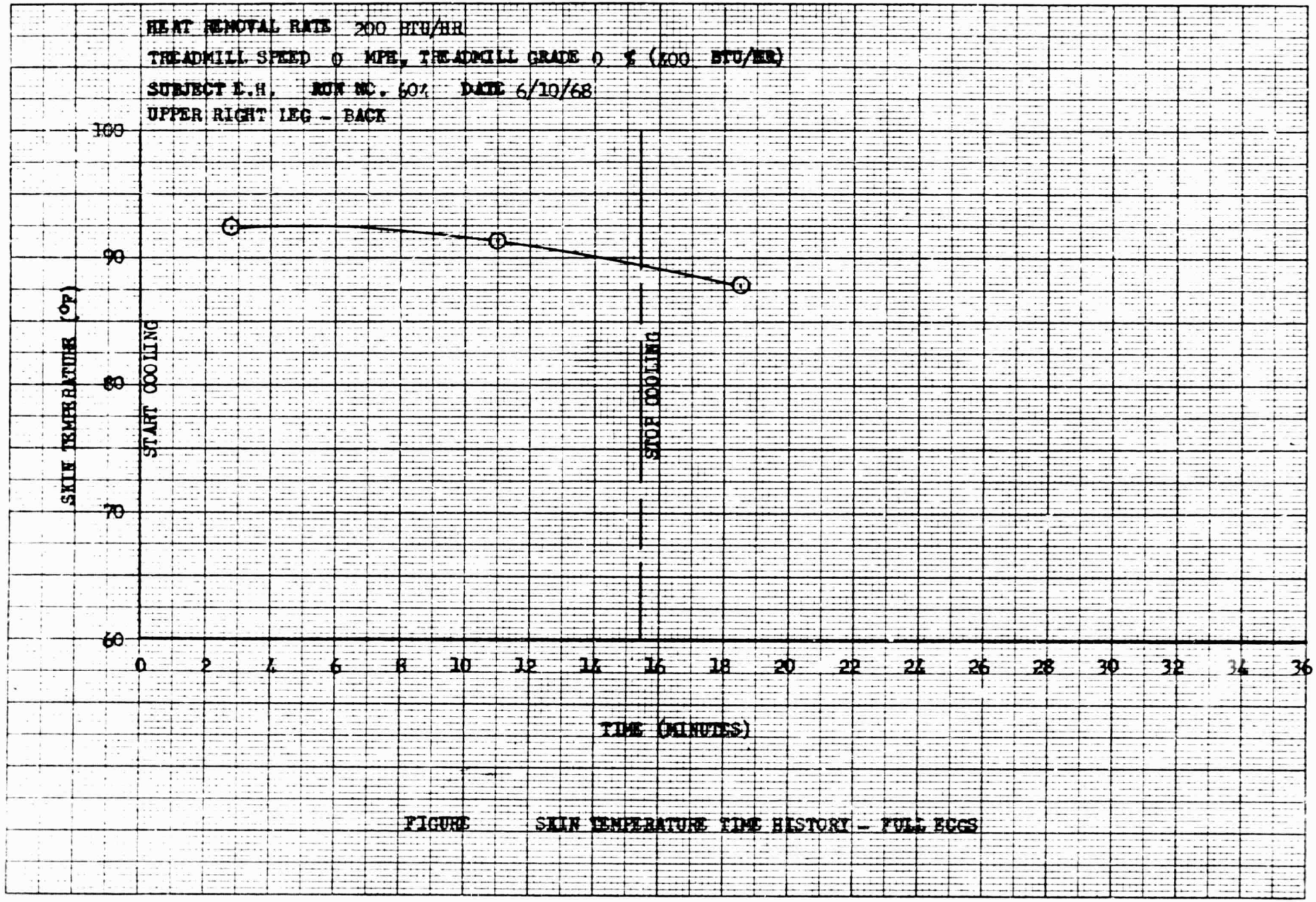


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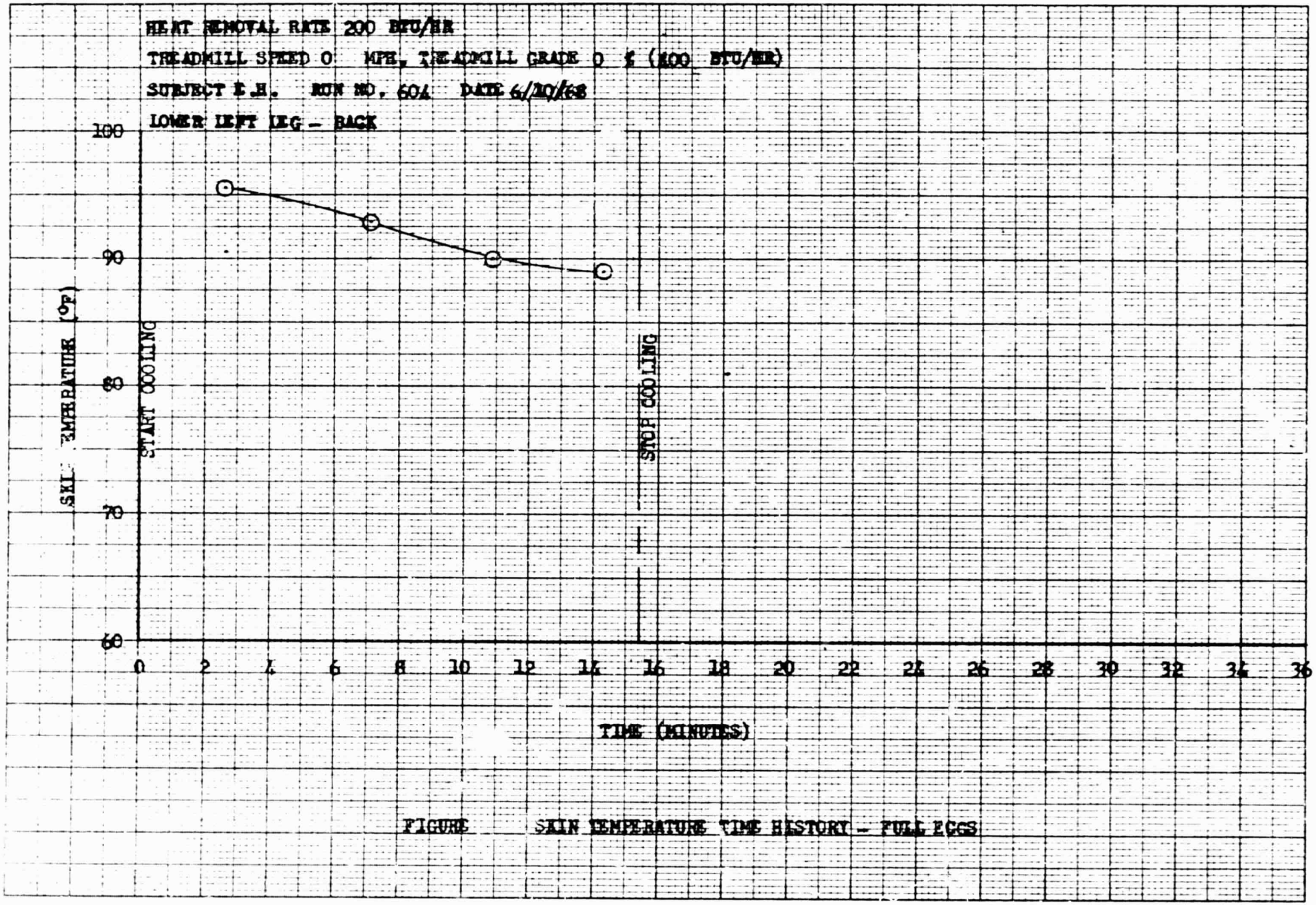


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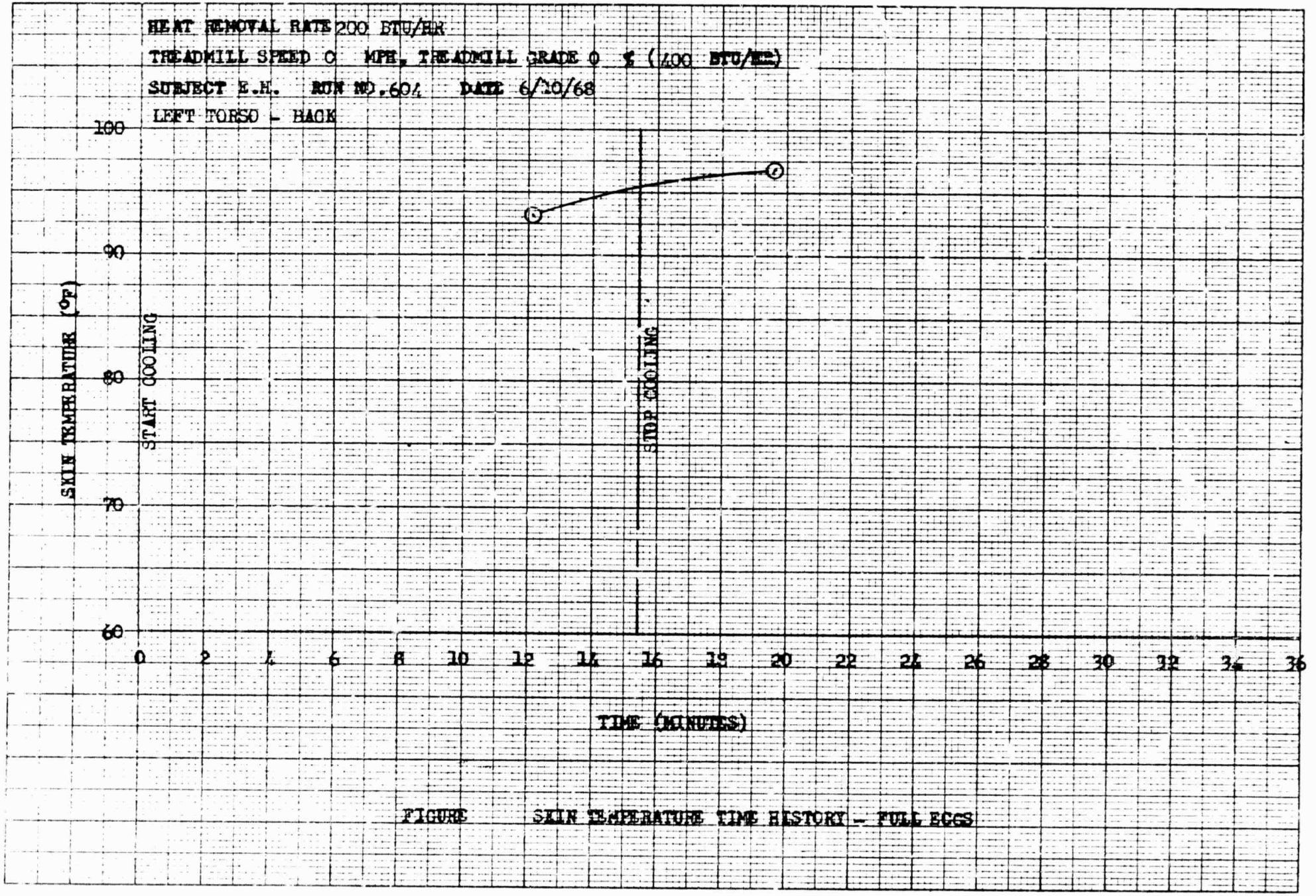


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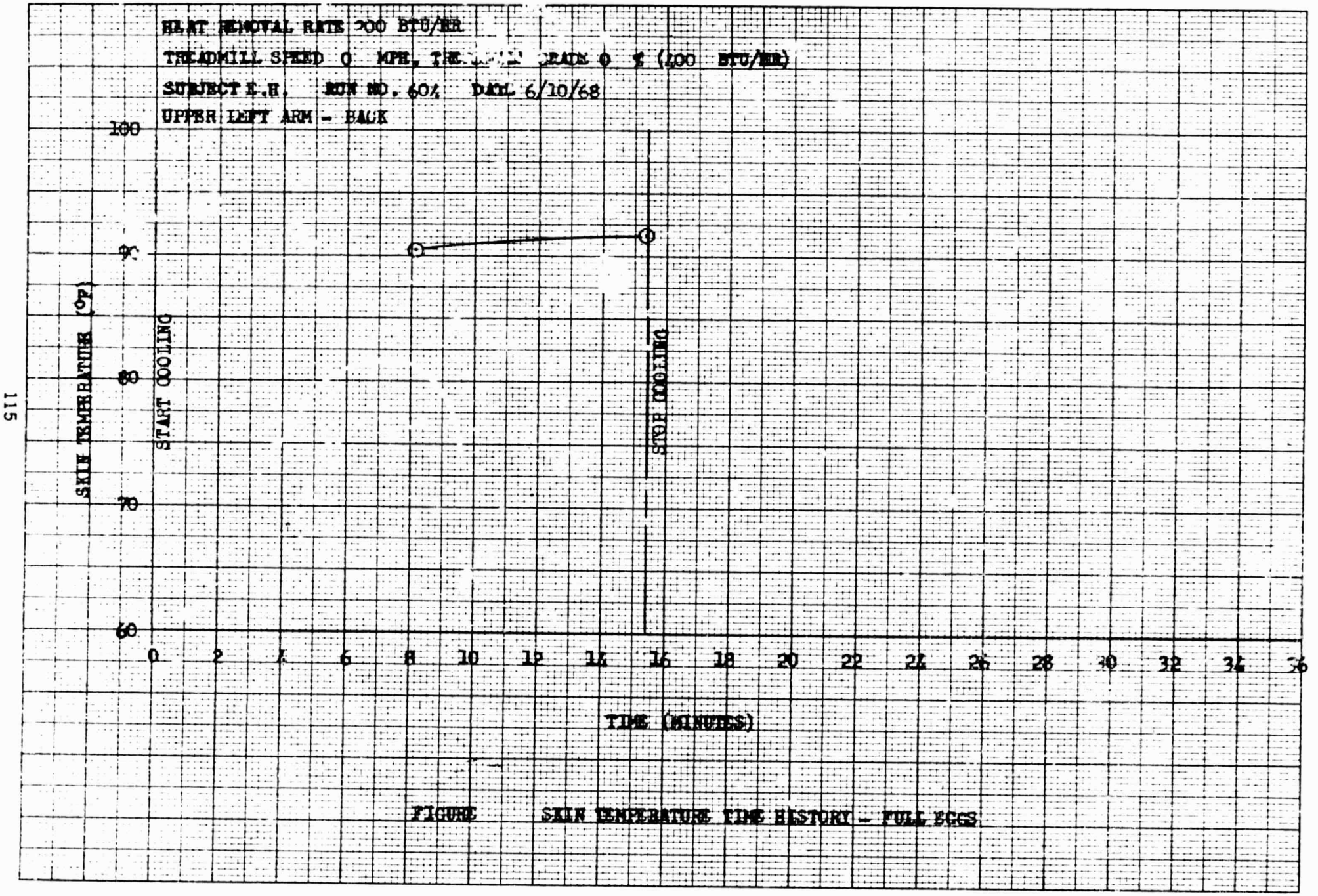


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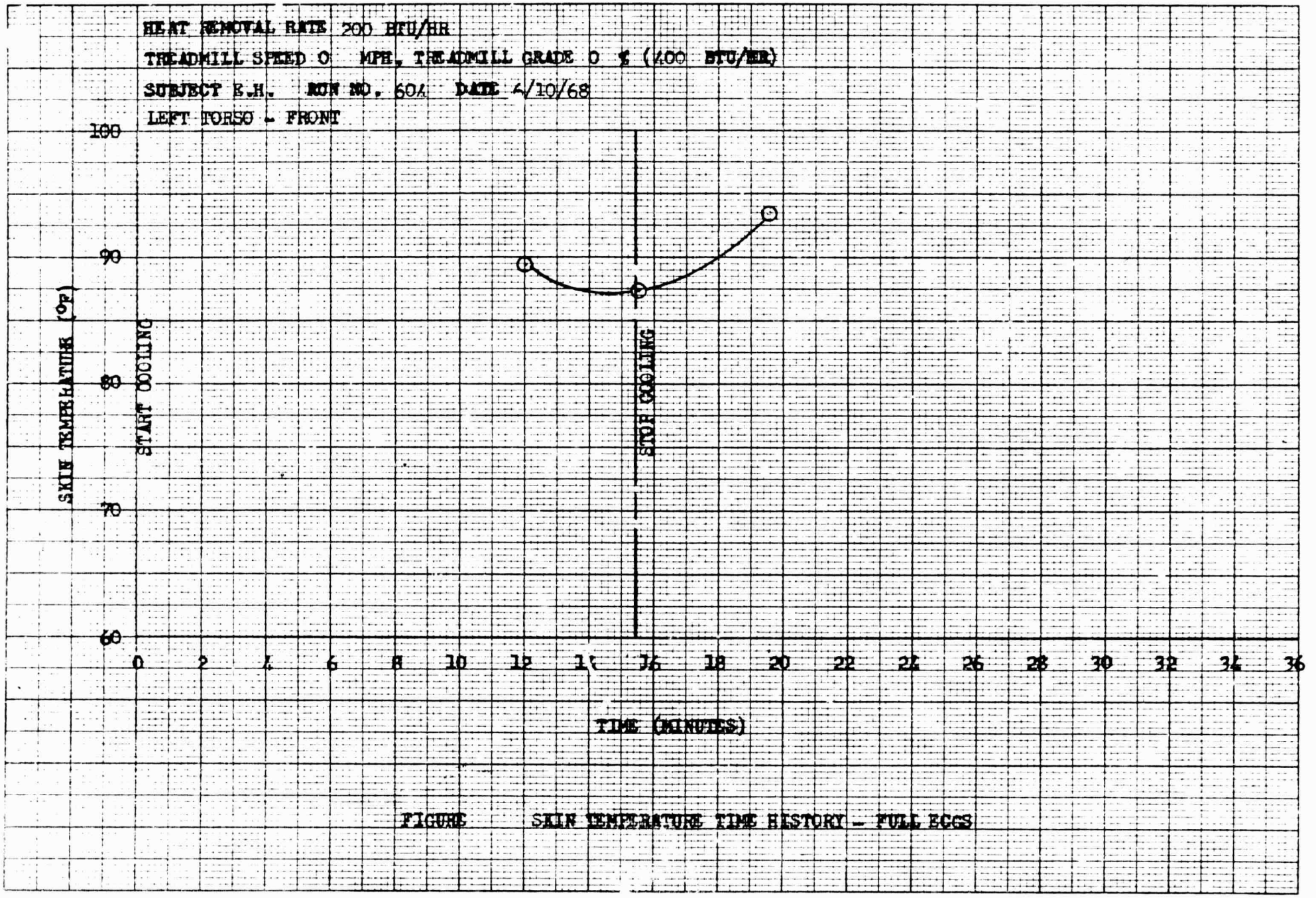


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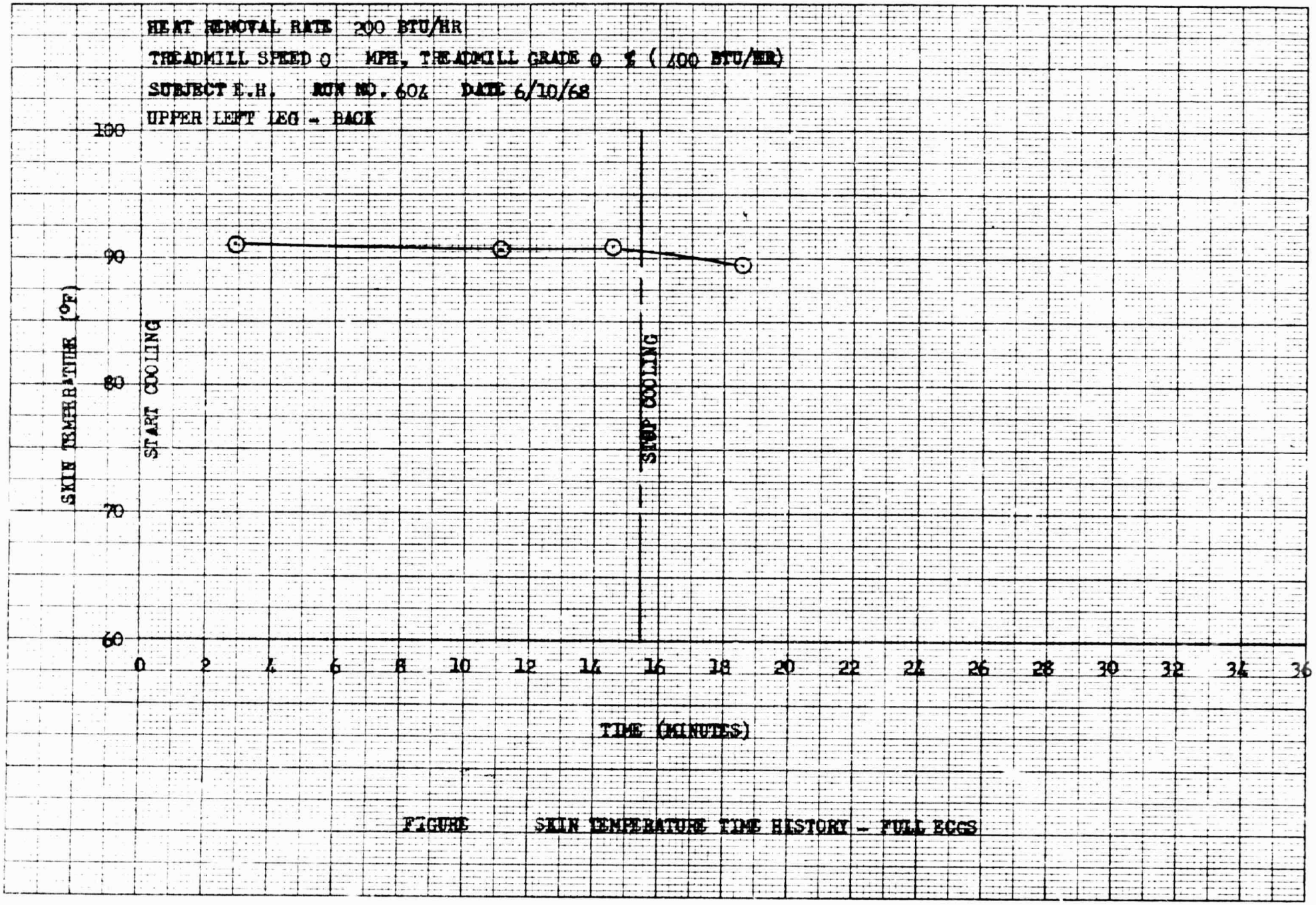


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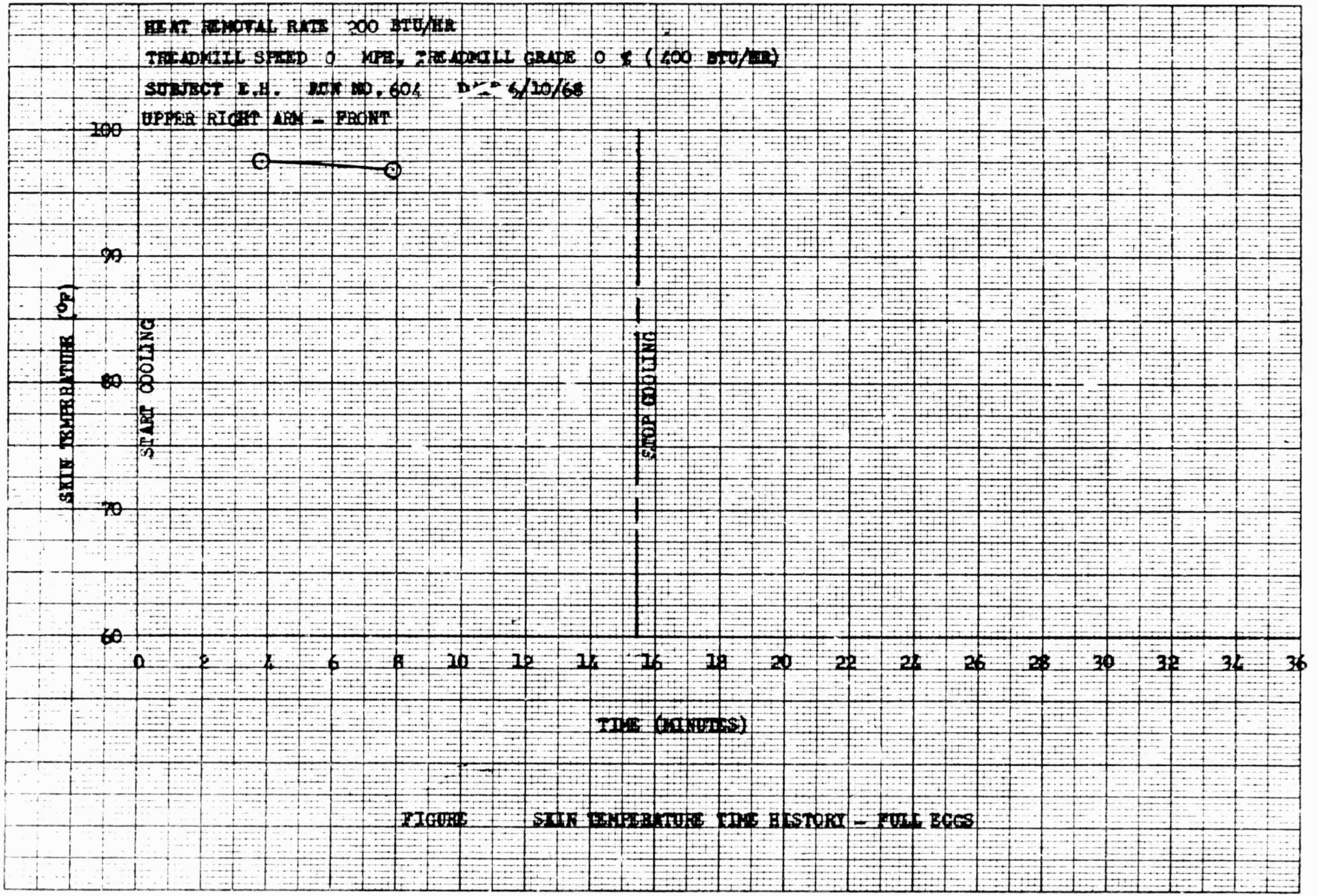


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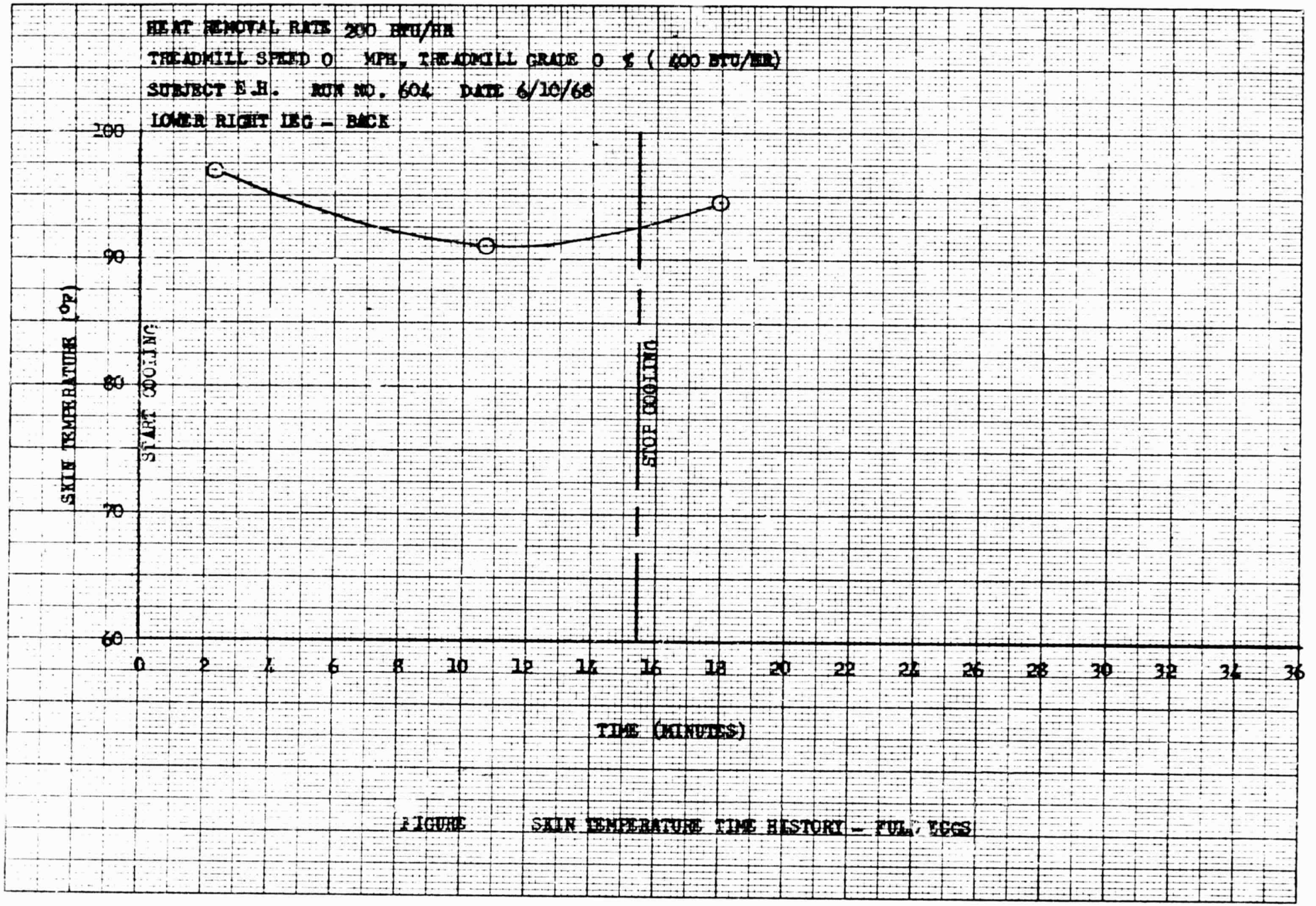


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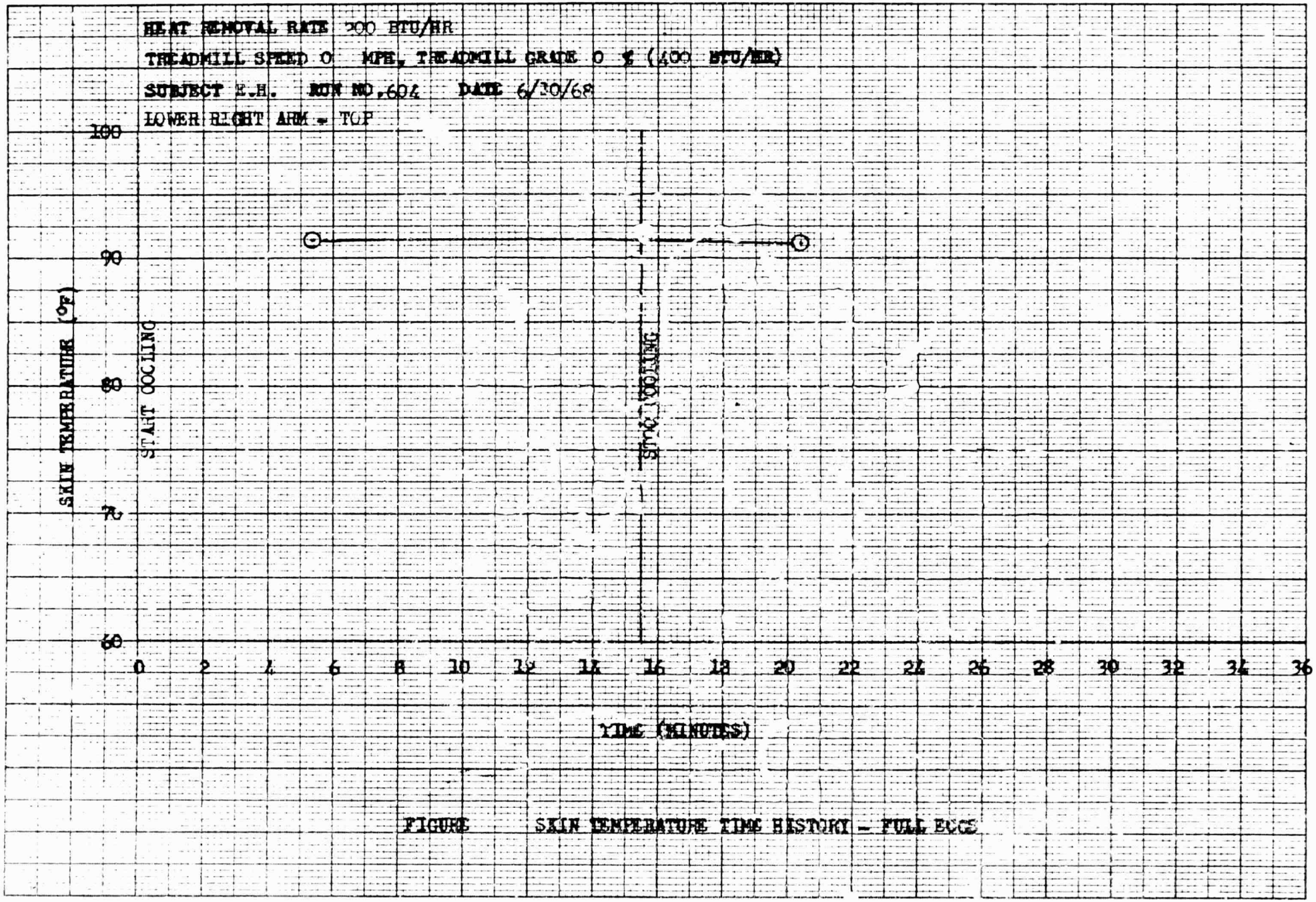


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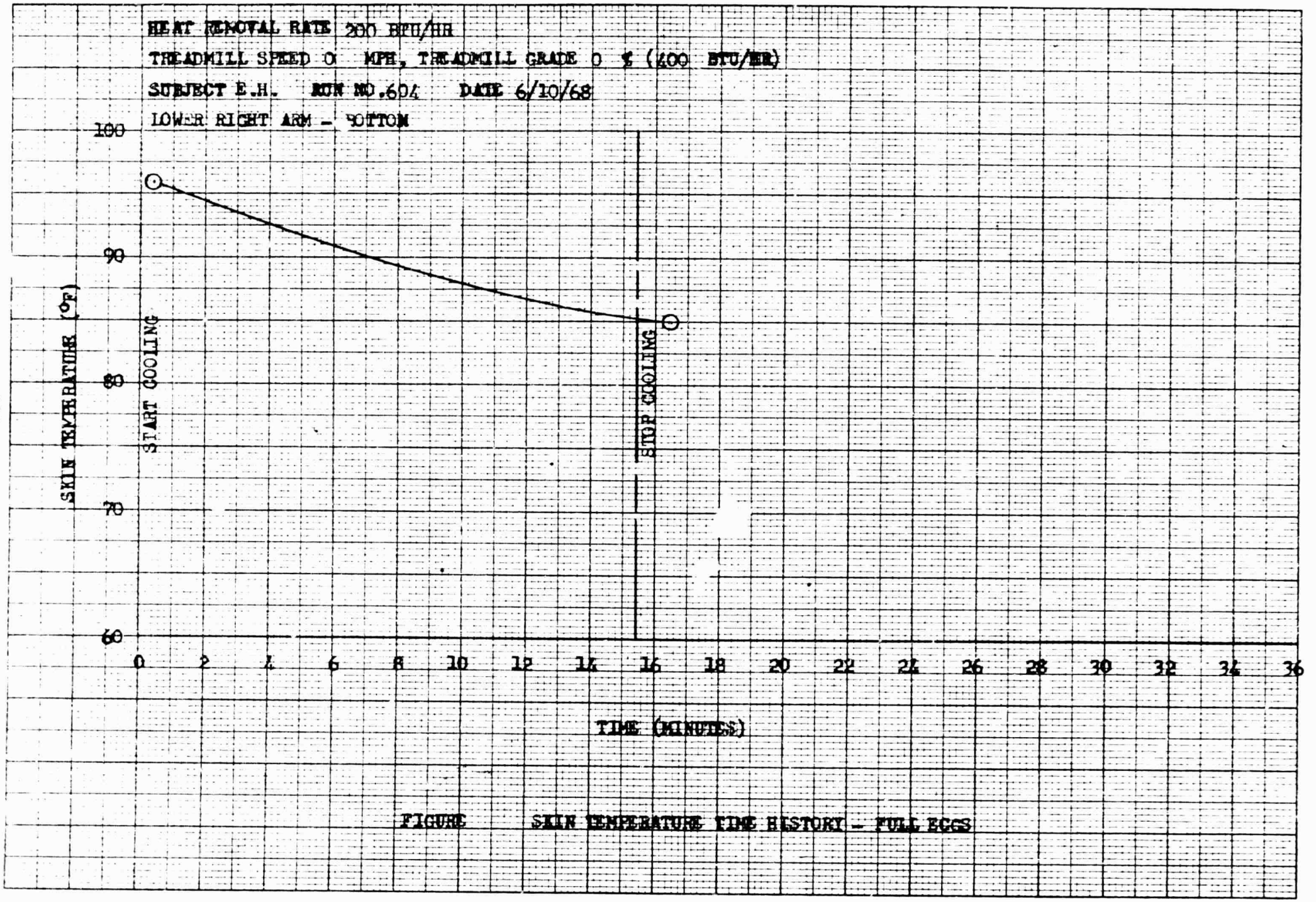


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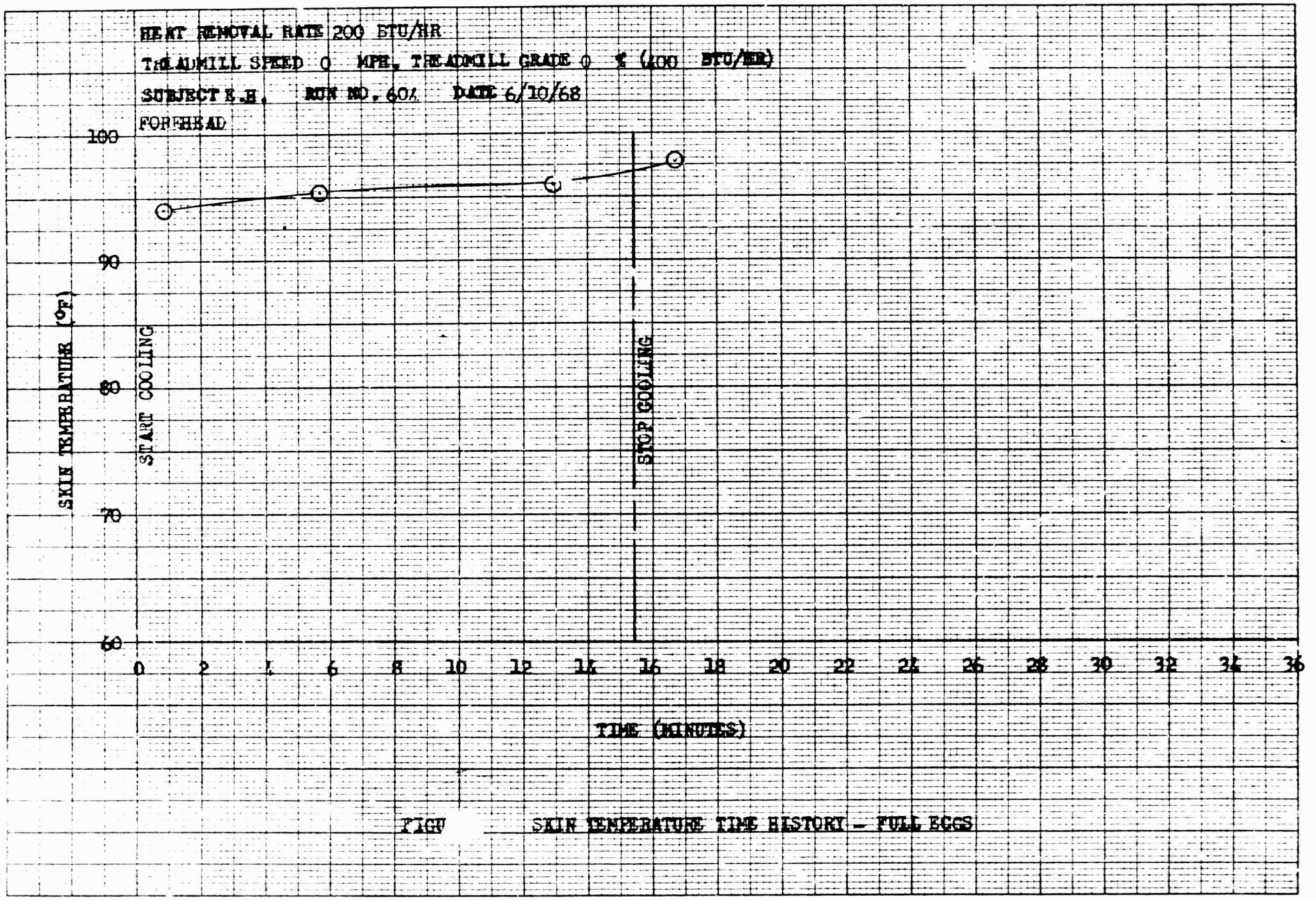


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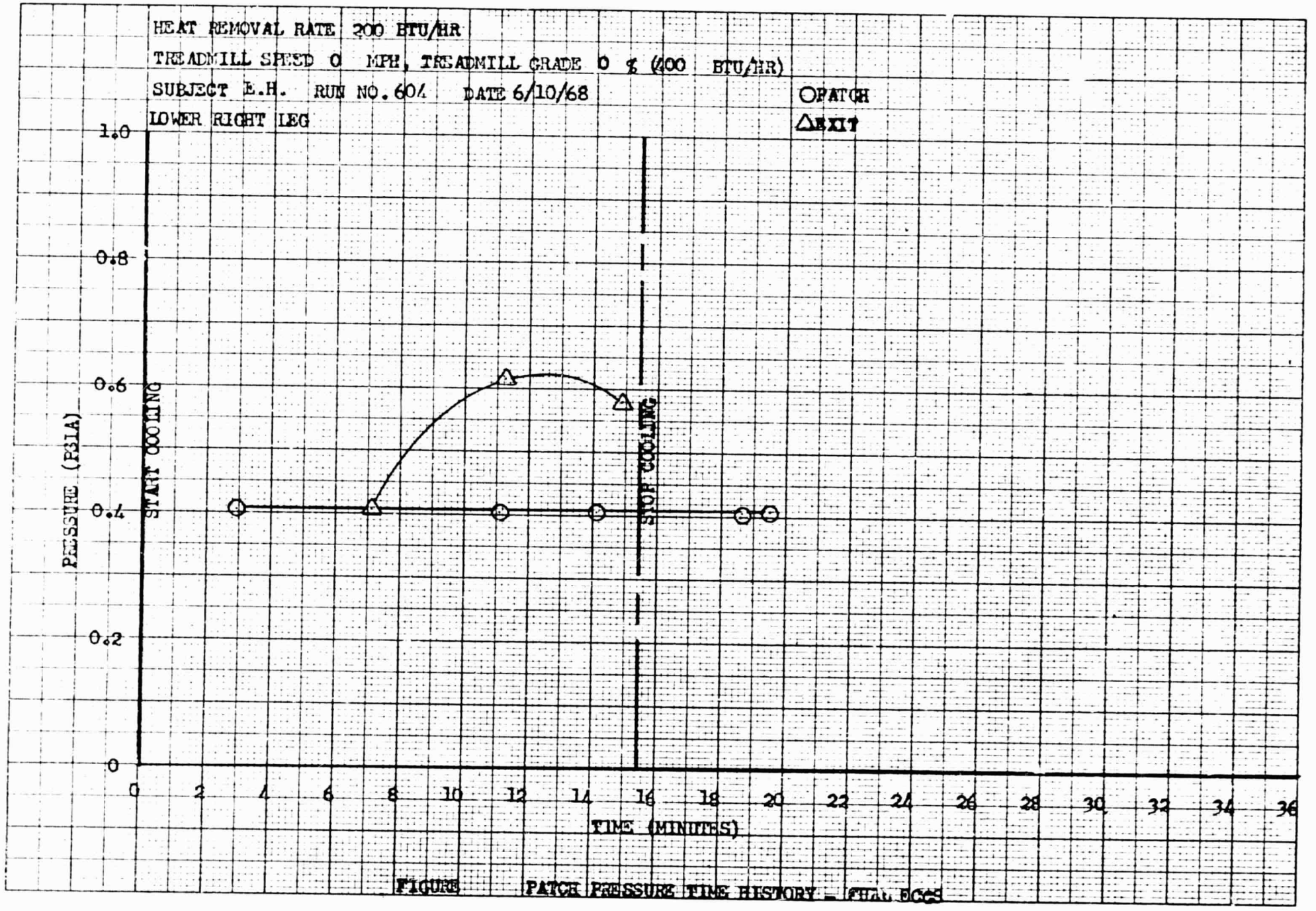


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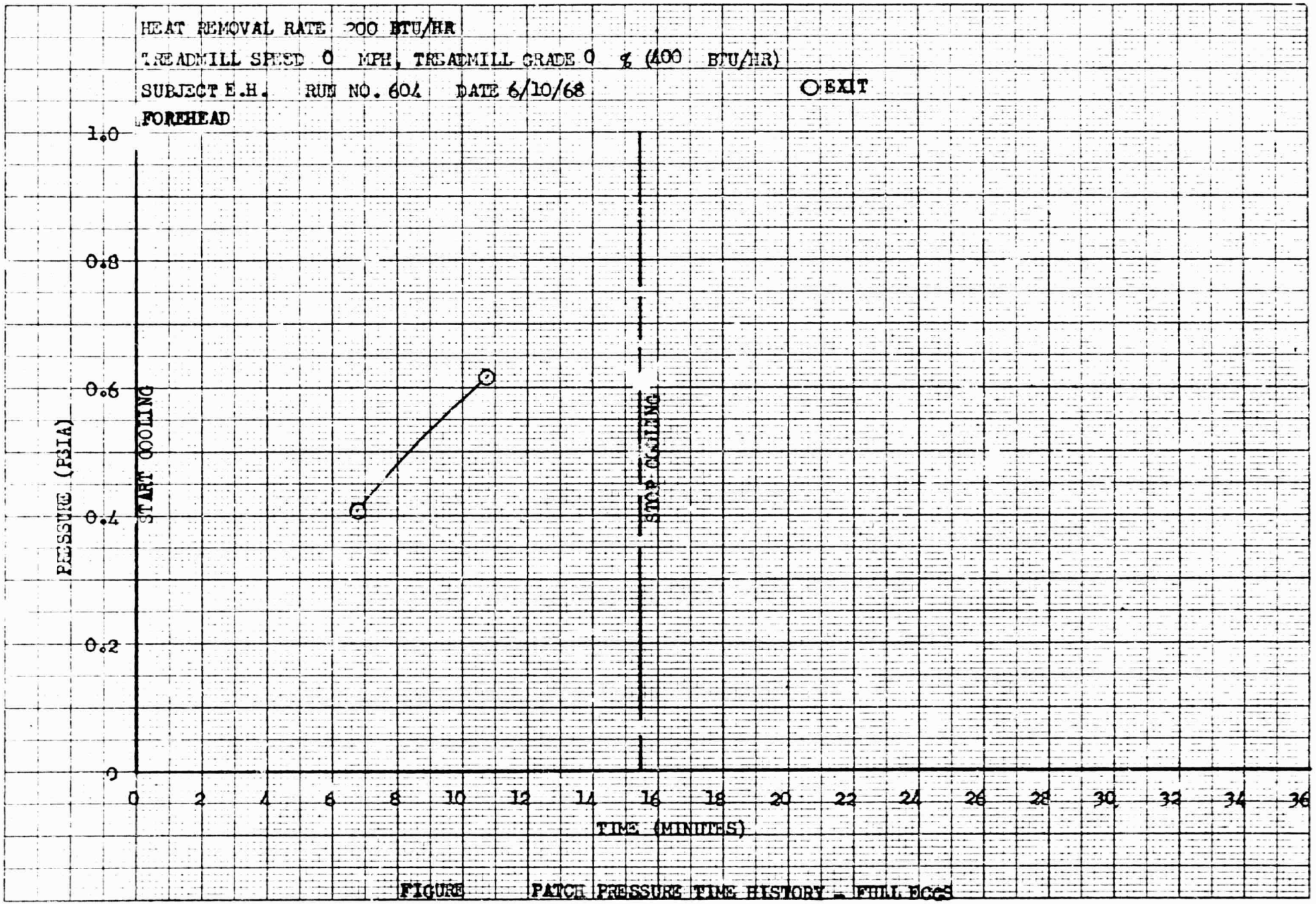


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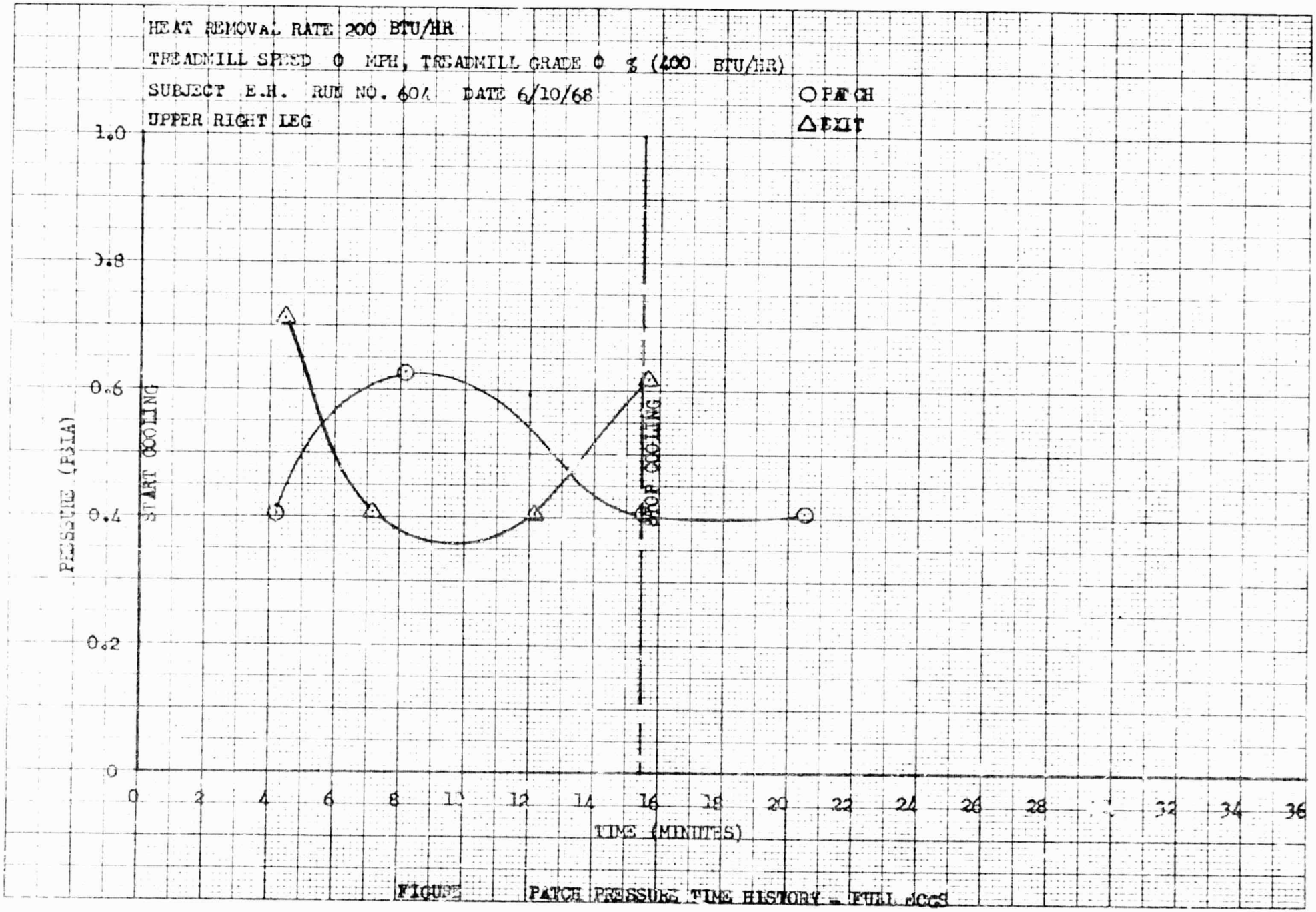


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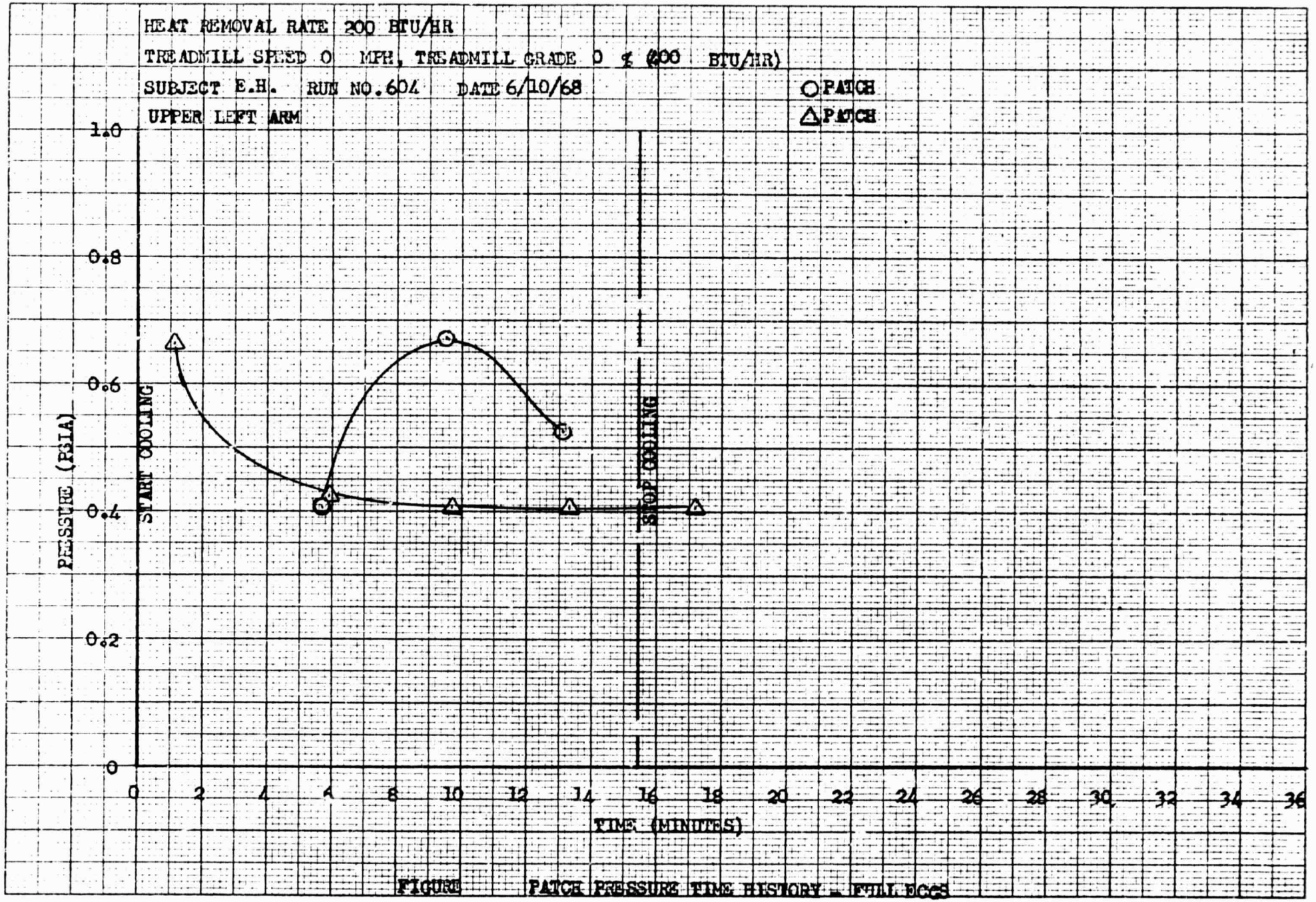


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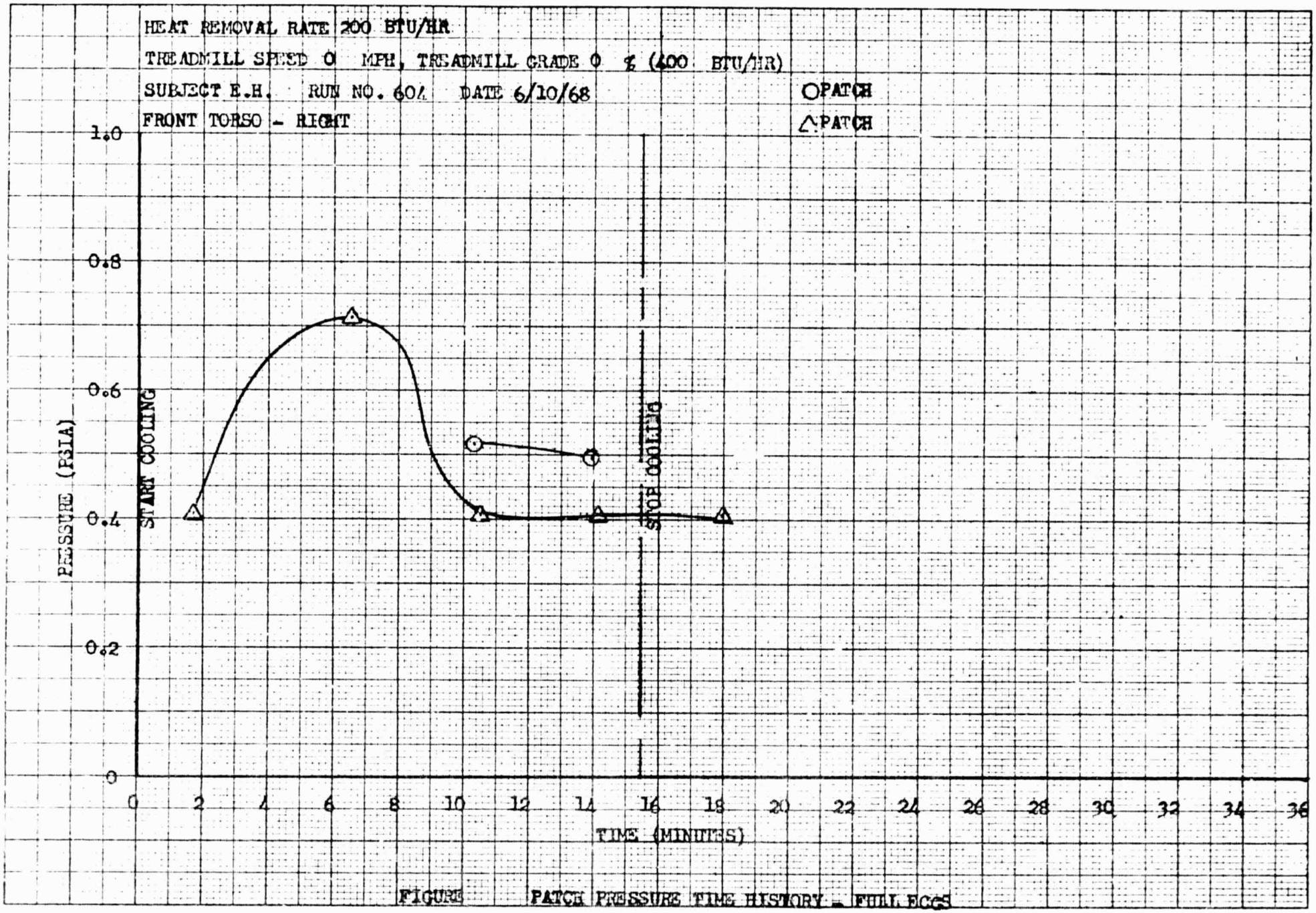


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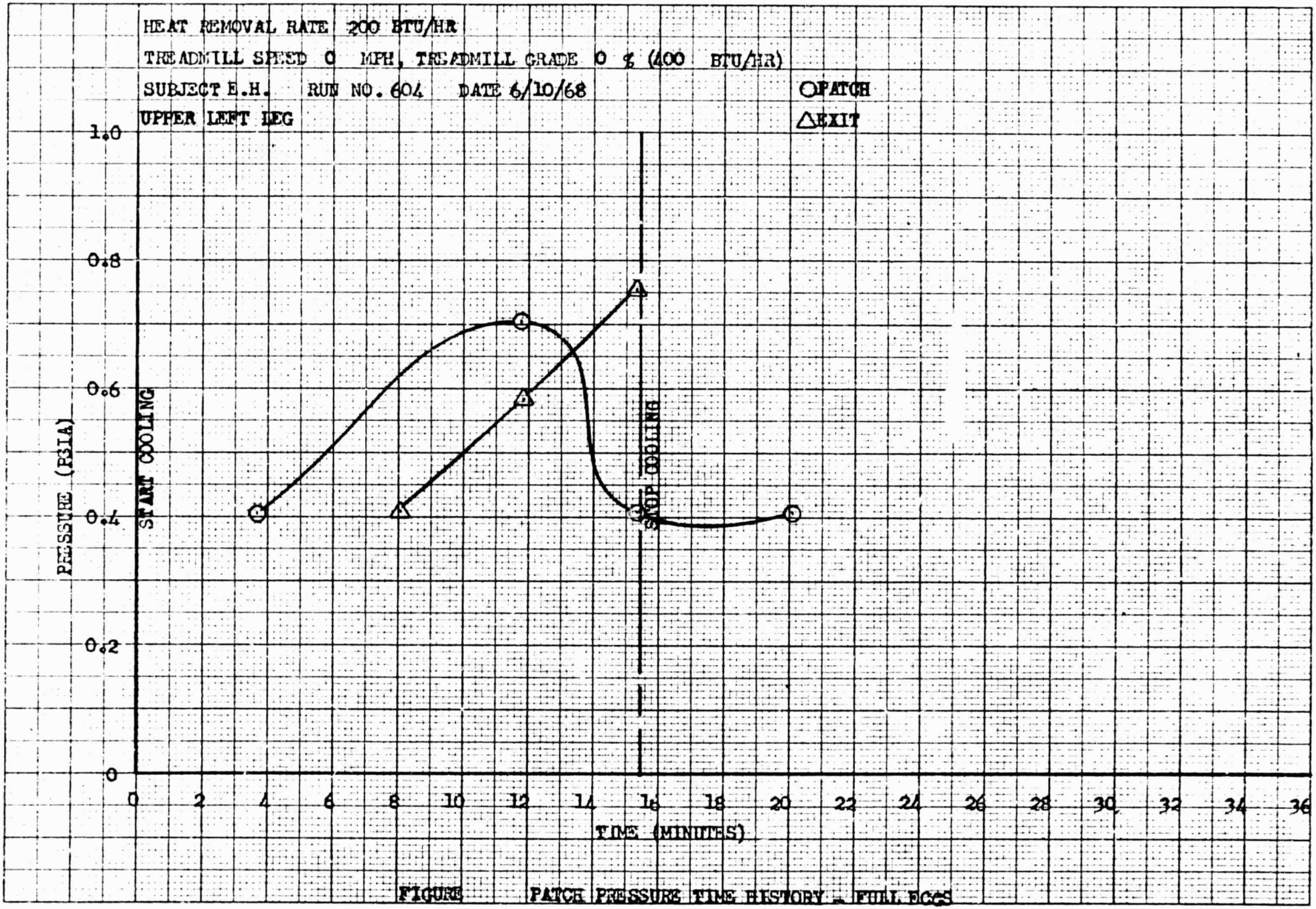


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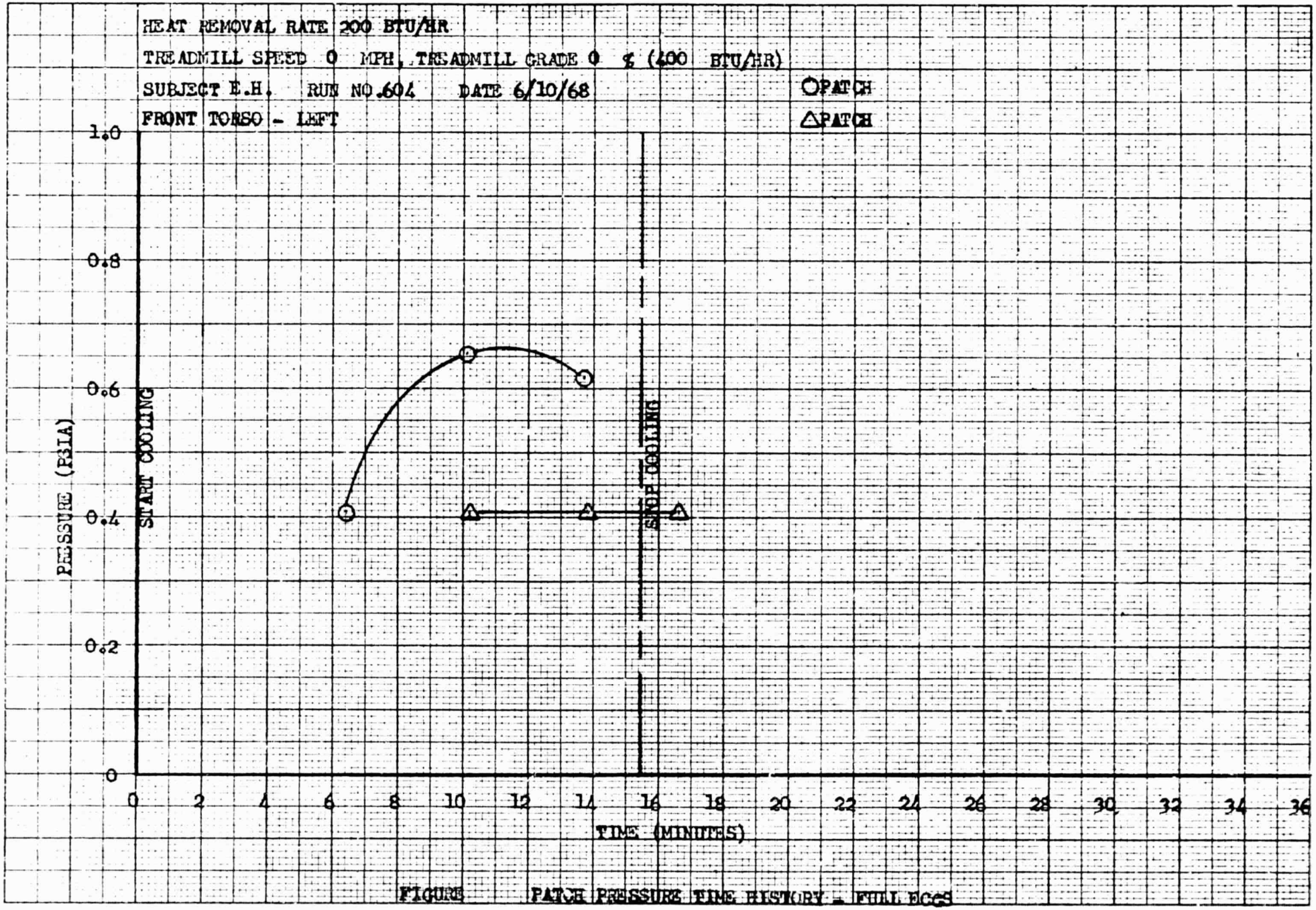


FIGURE PATCH PRESSURE TIME HISTORY - FULL ECGS

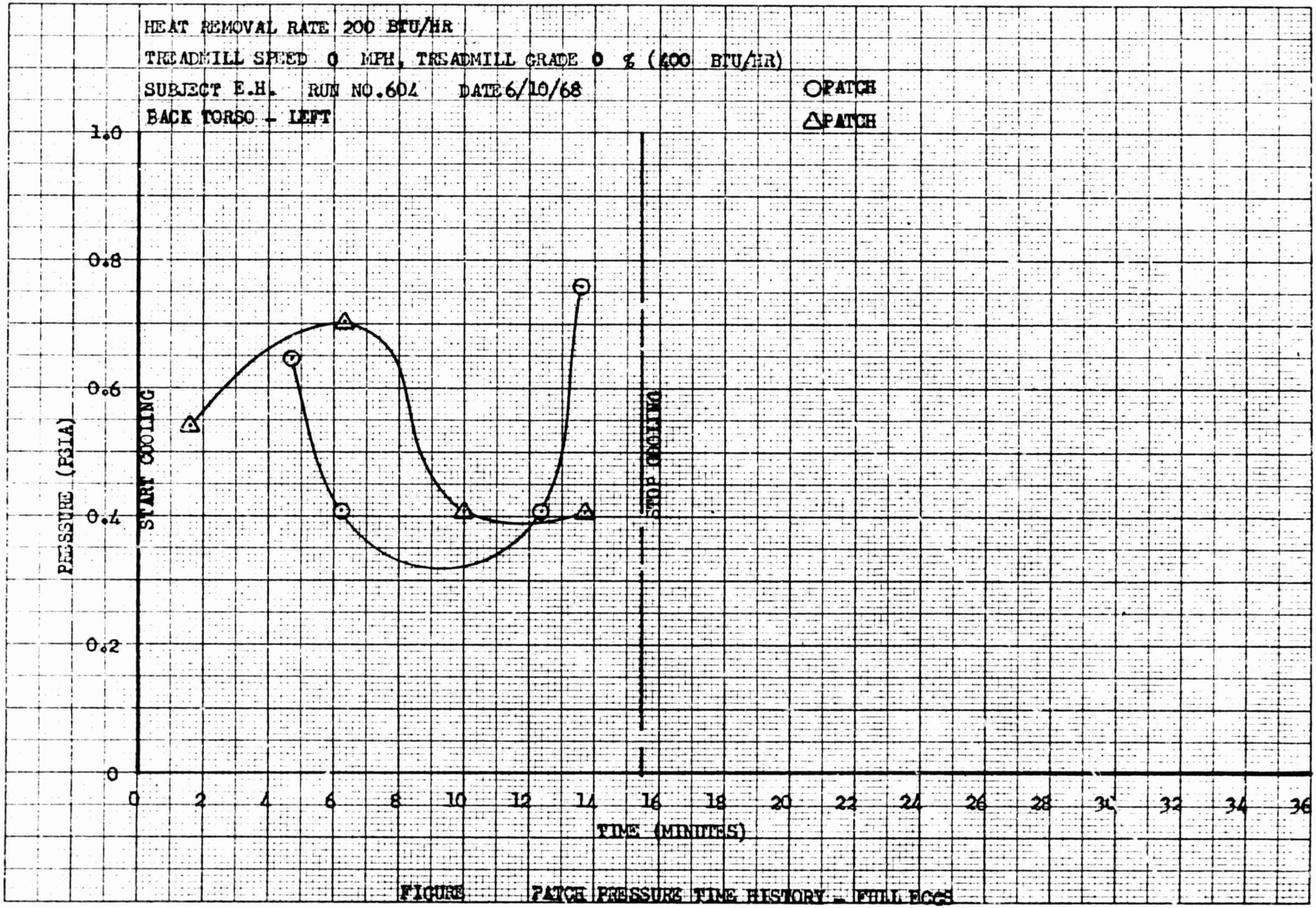


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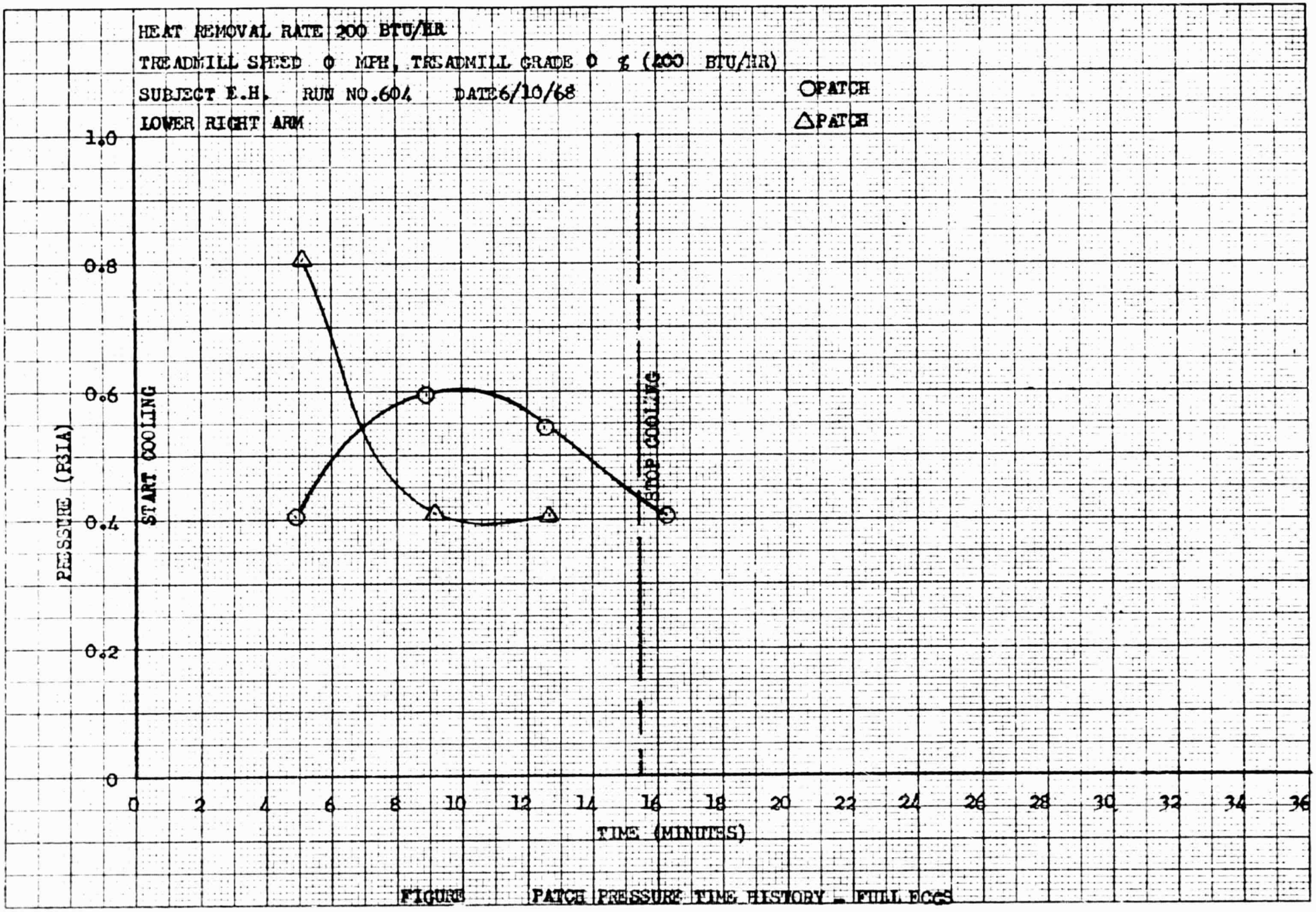


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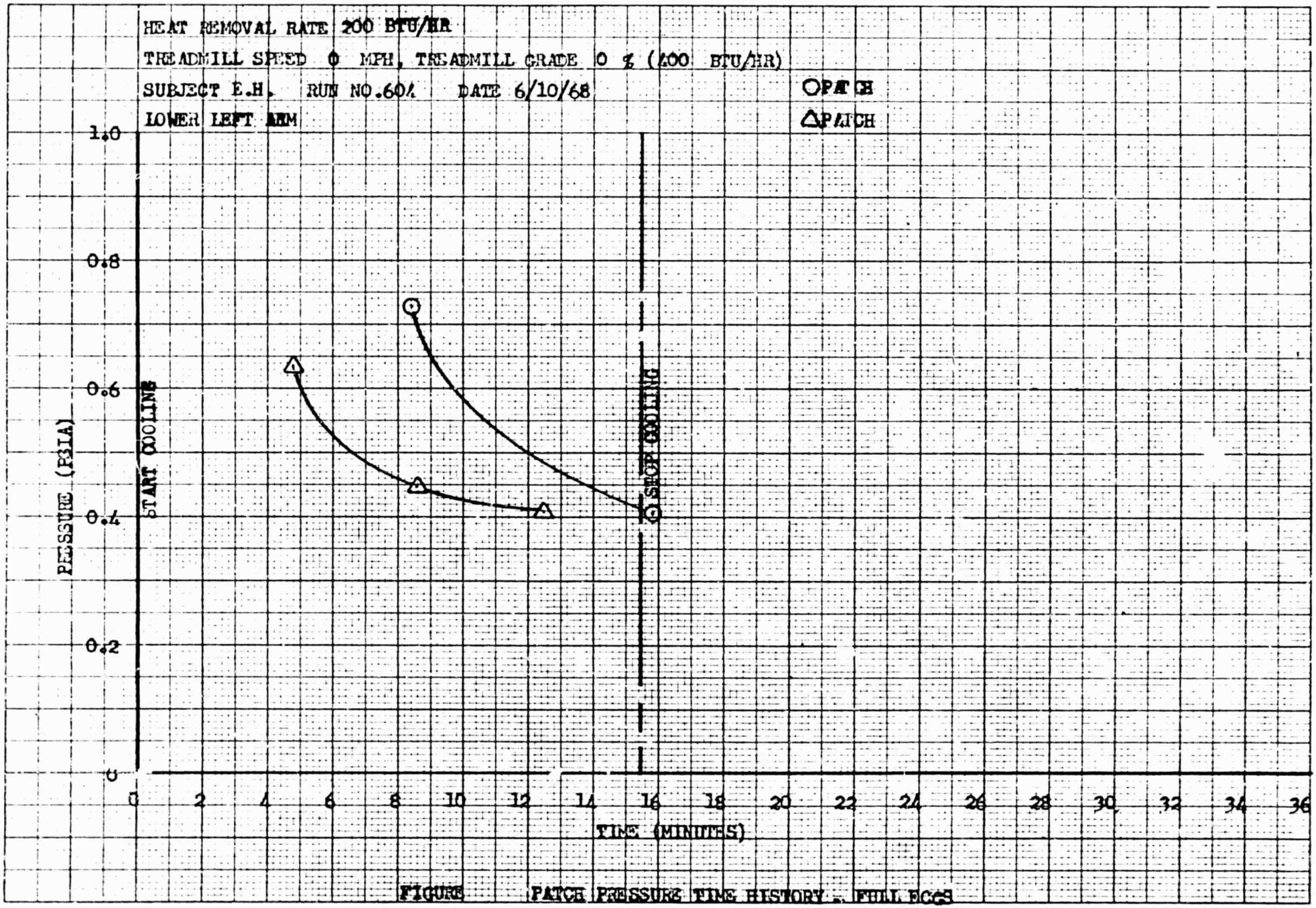


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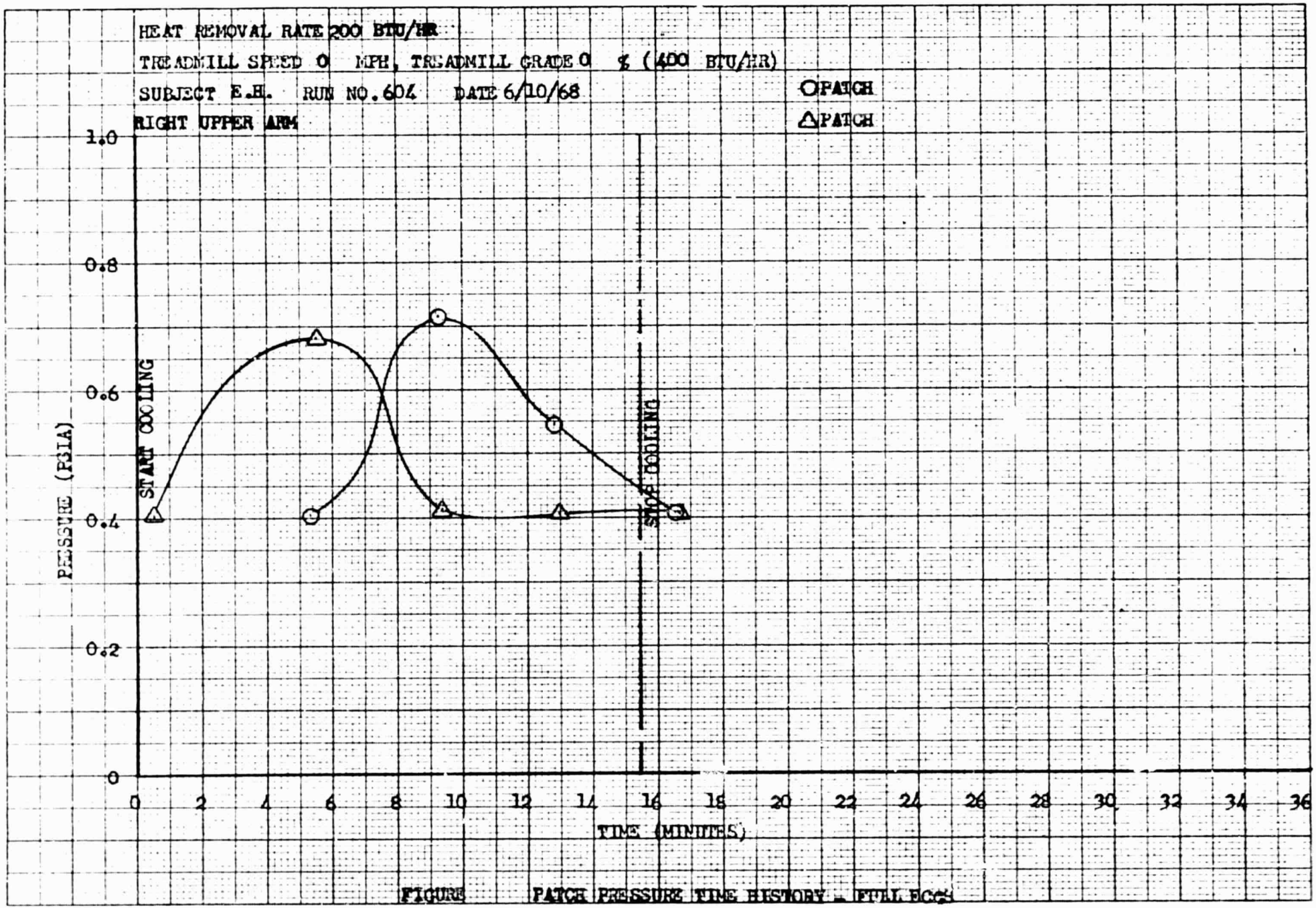


FIGURE PATCH PRESSURE TIME HISTORY - FULL ECG

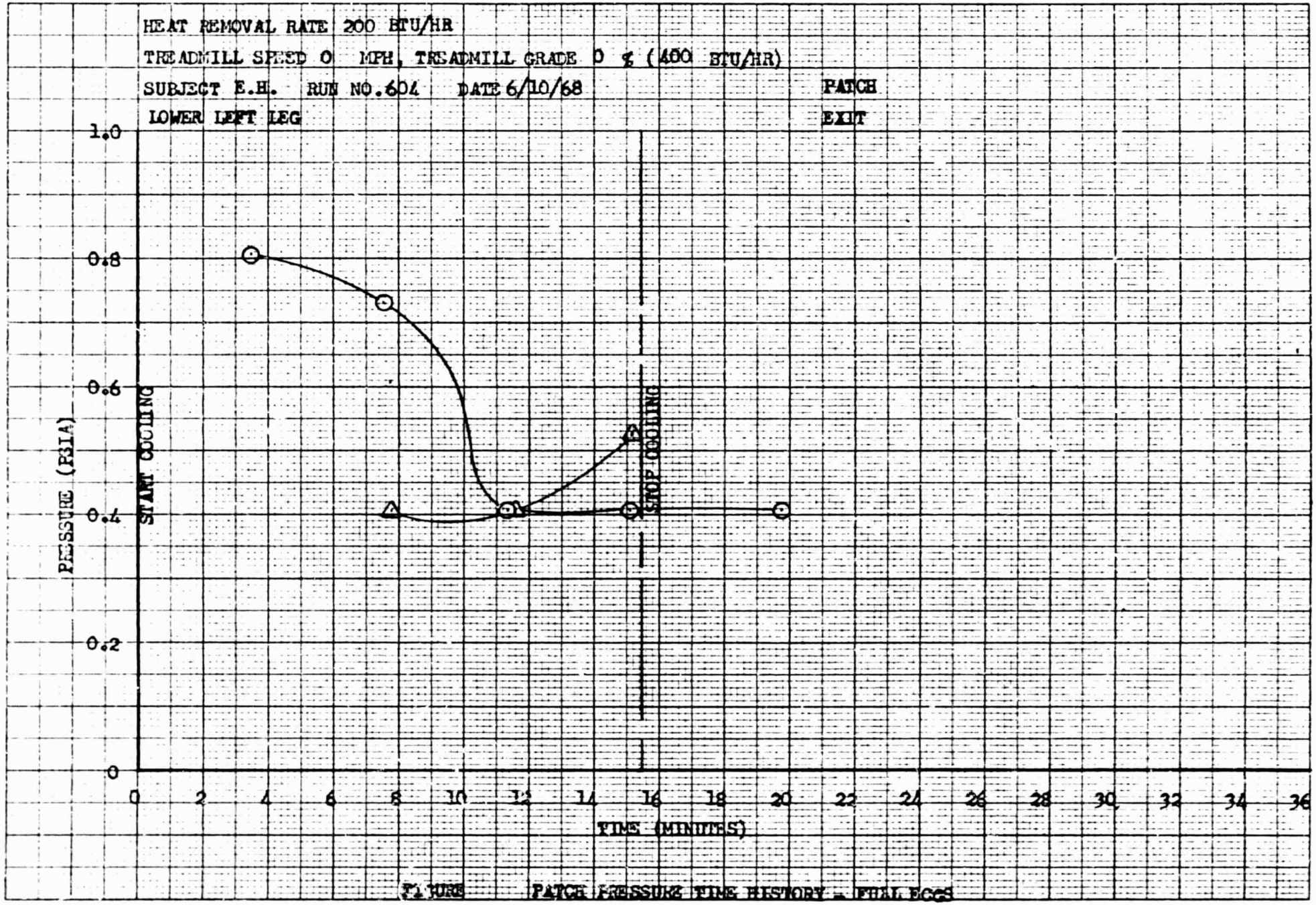


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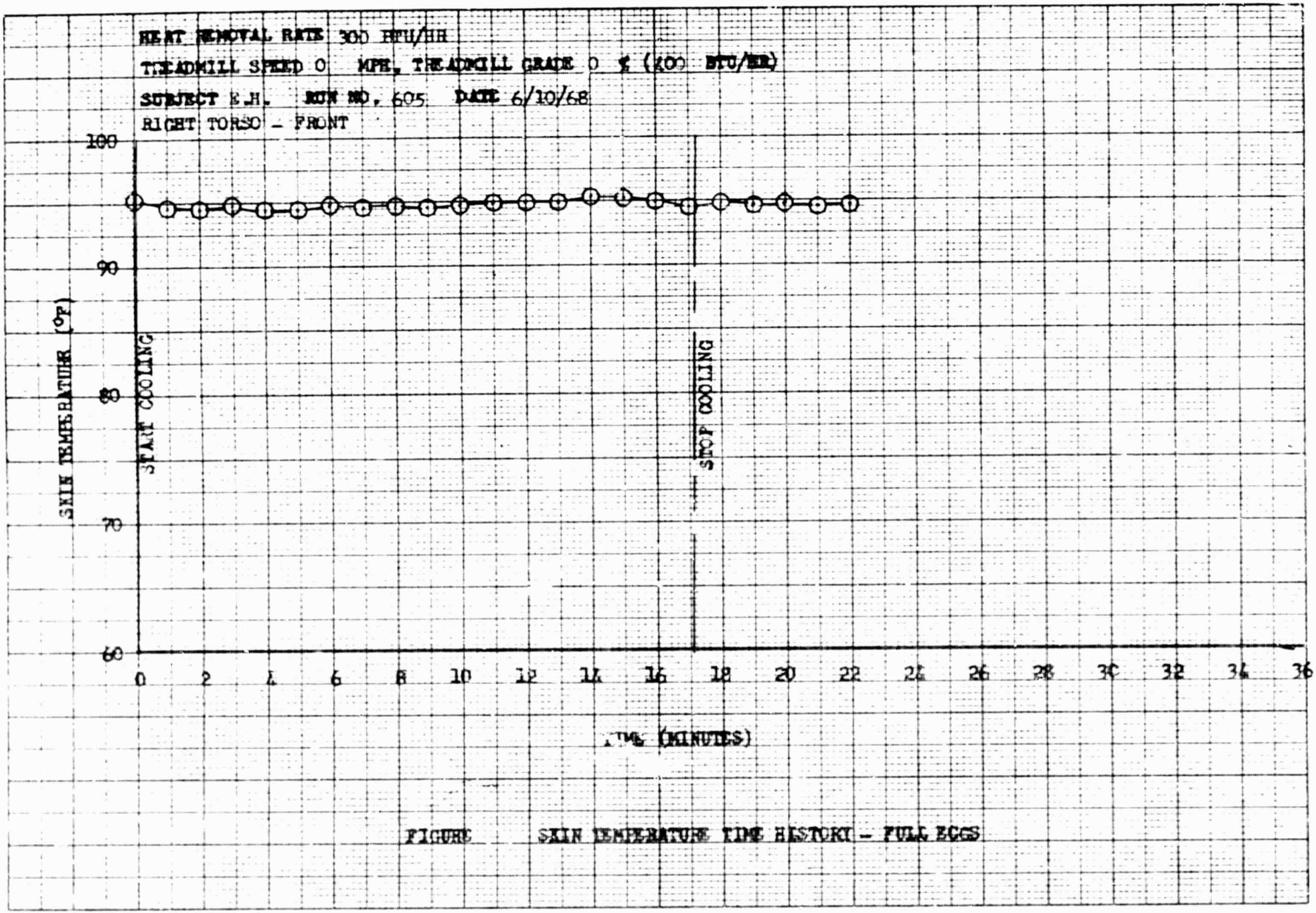


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL EGGS

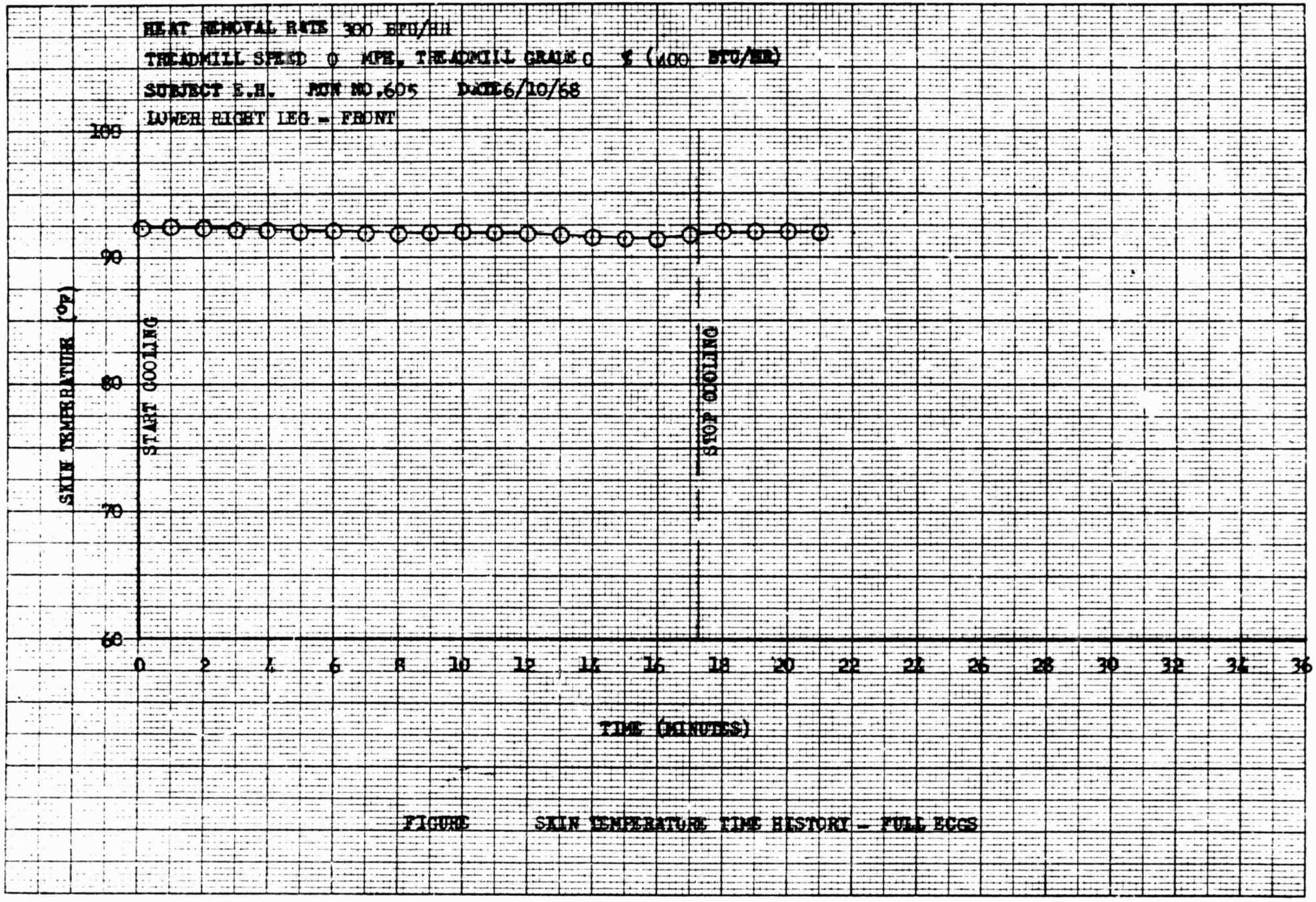


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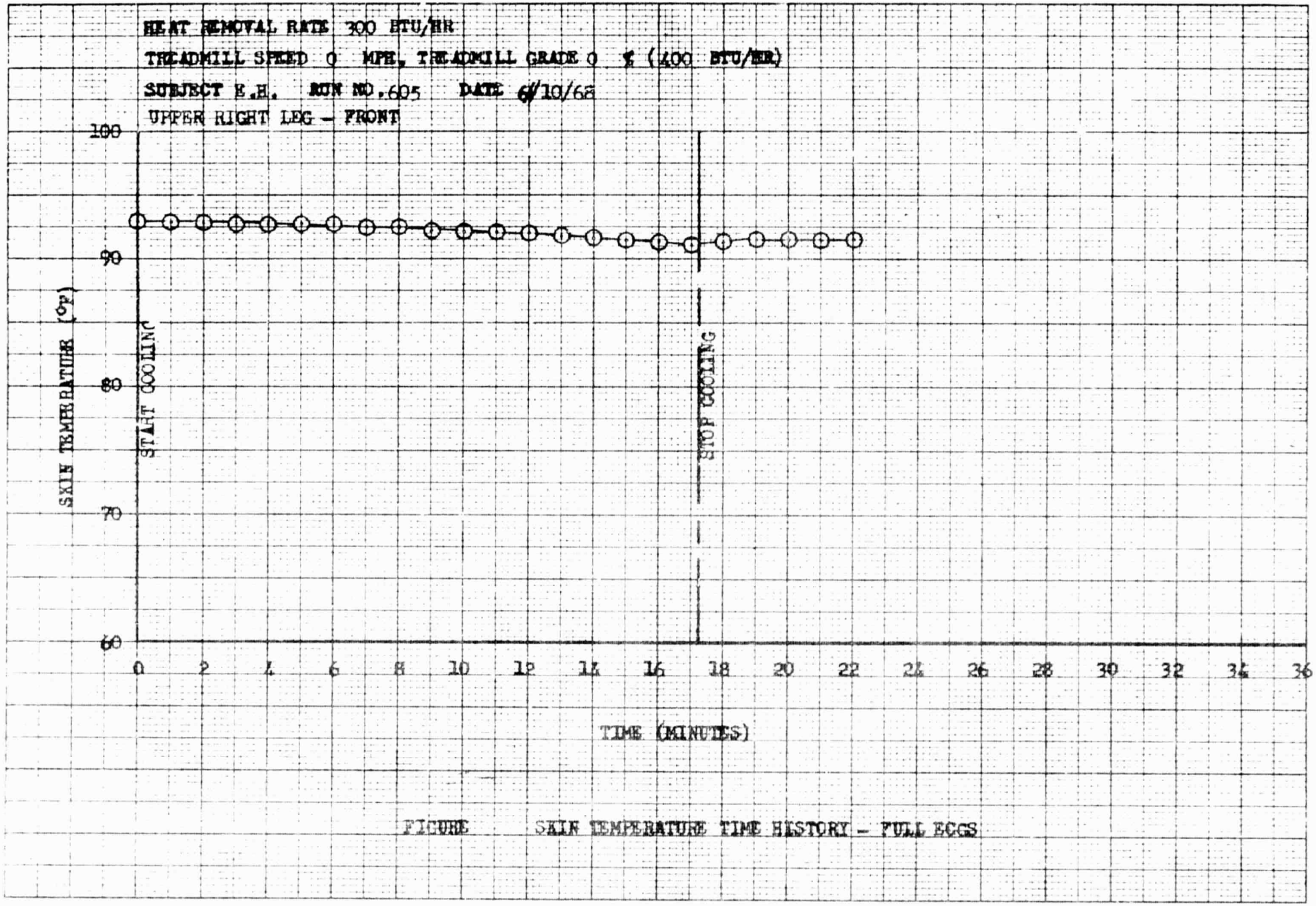


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

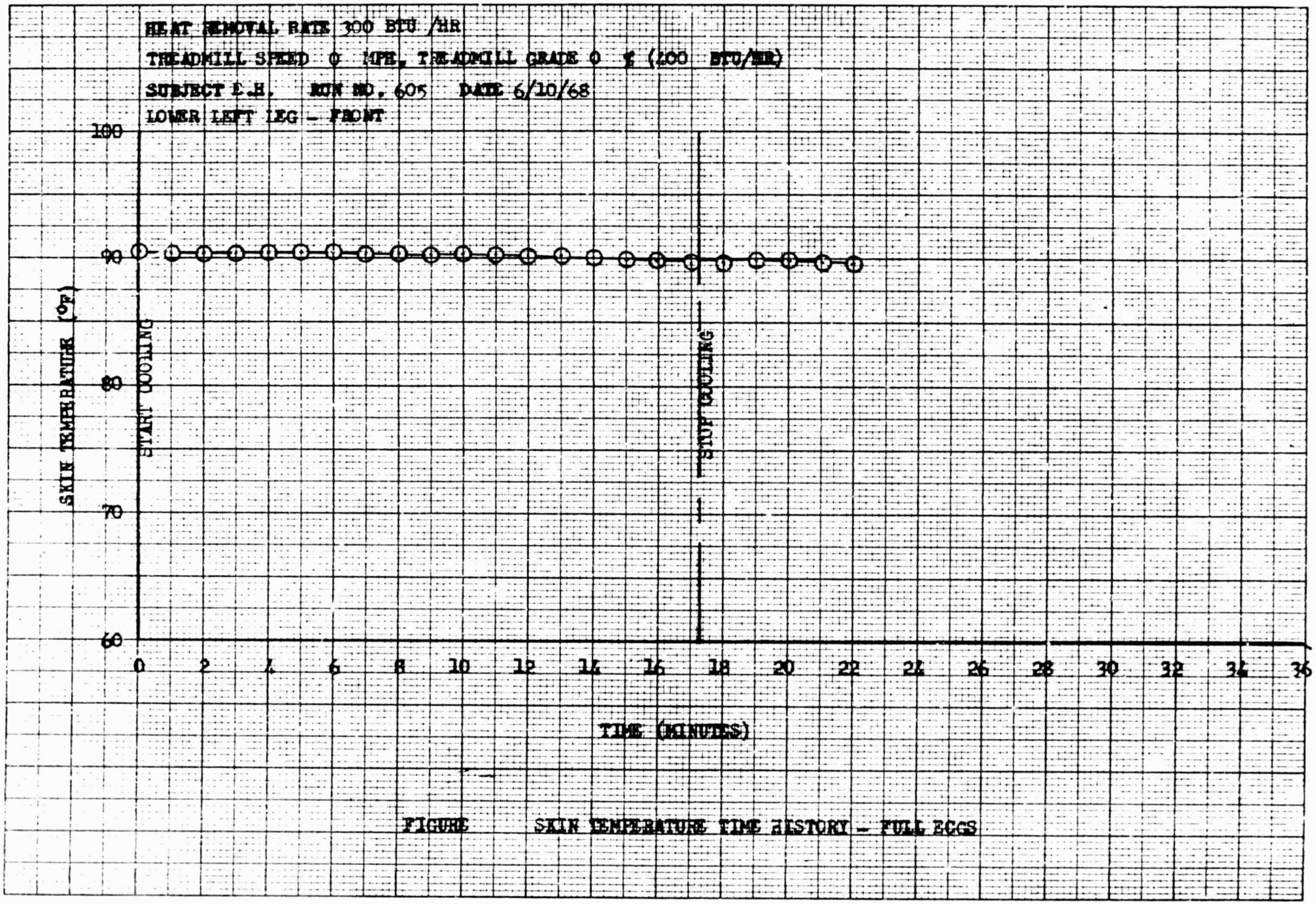


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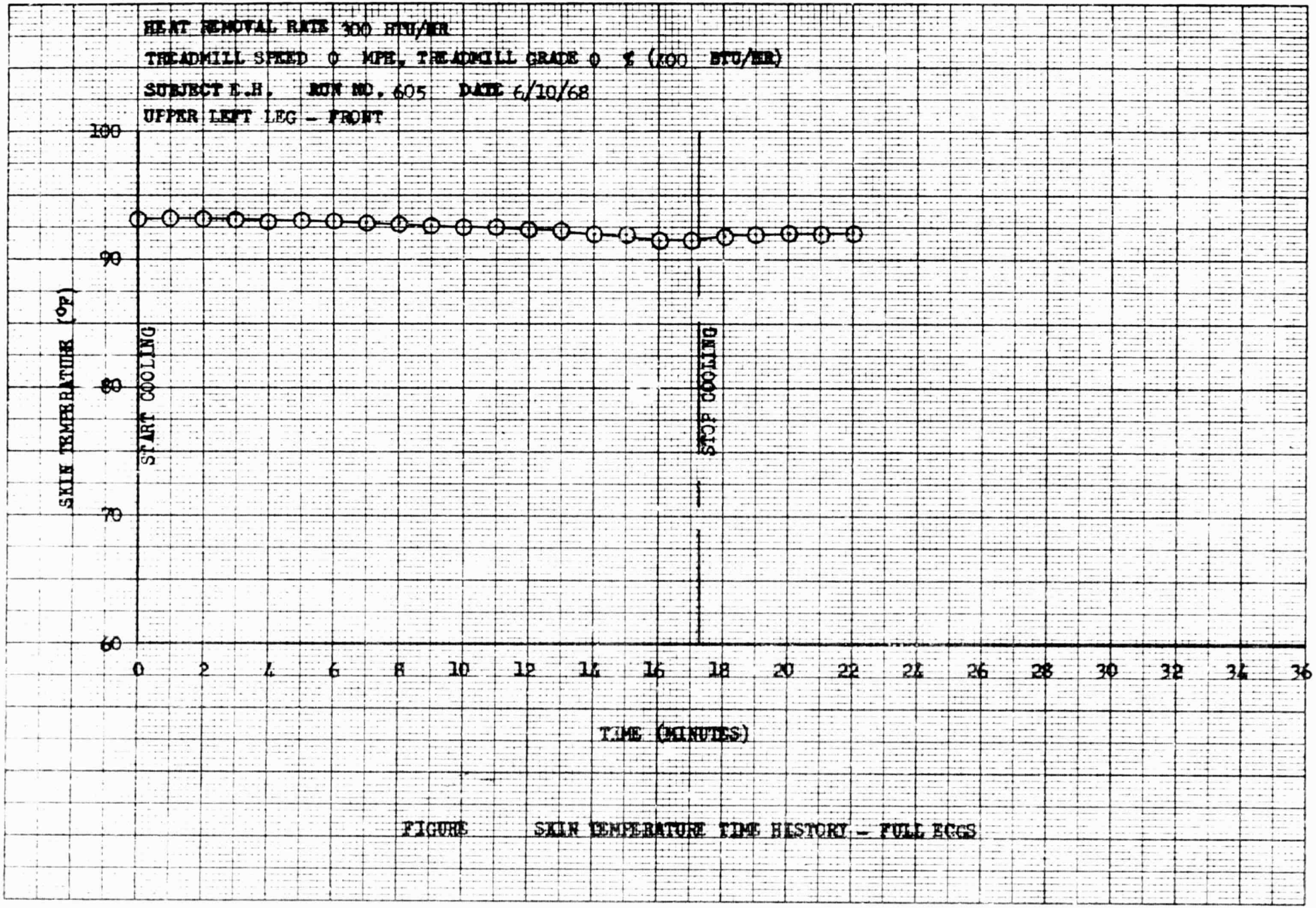


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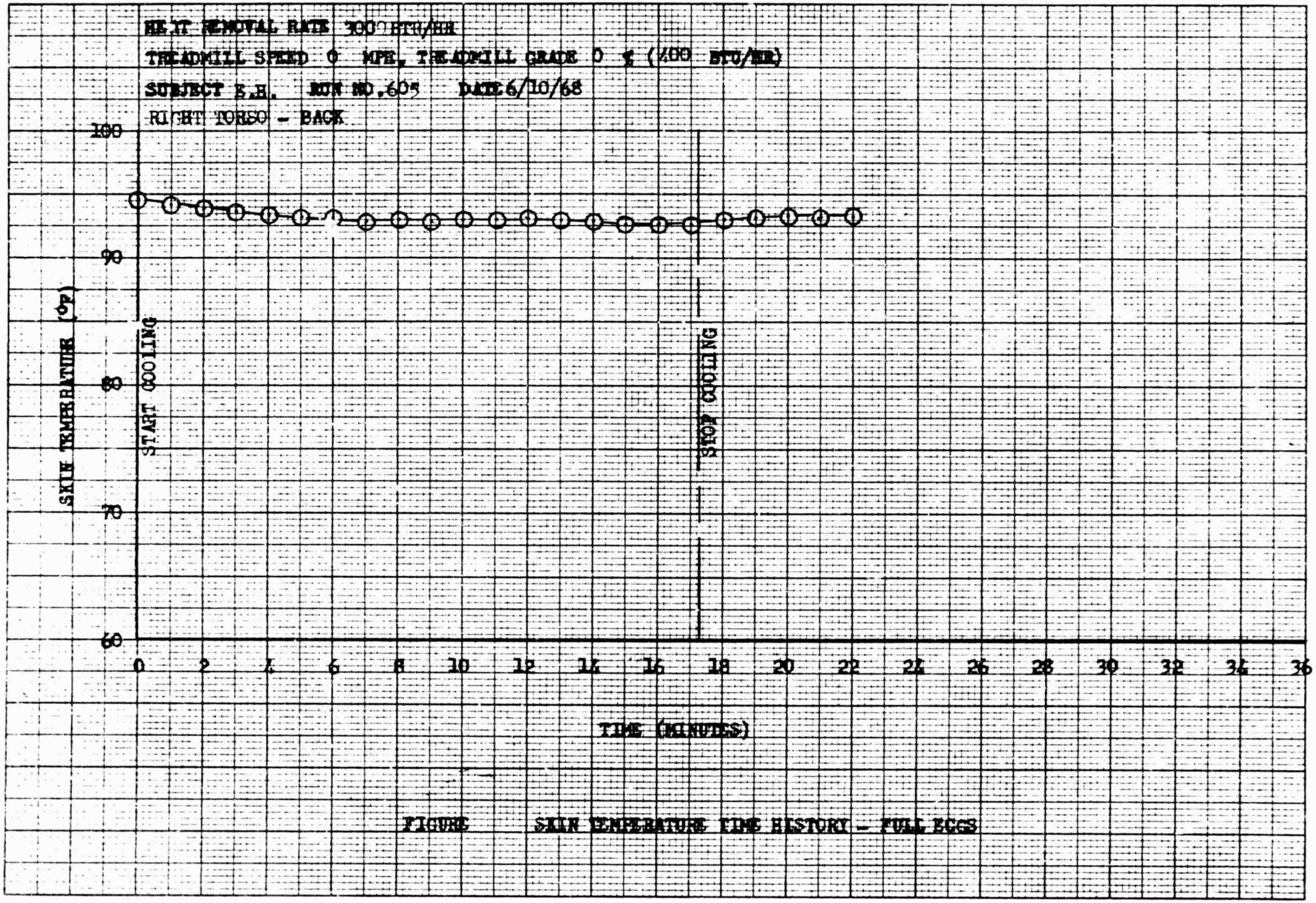


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

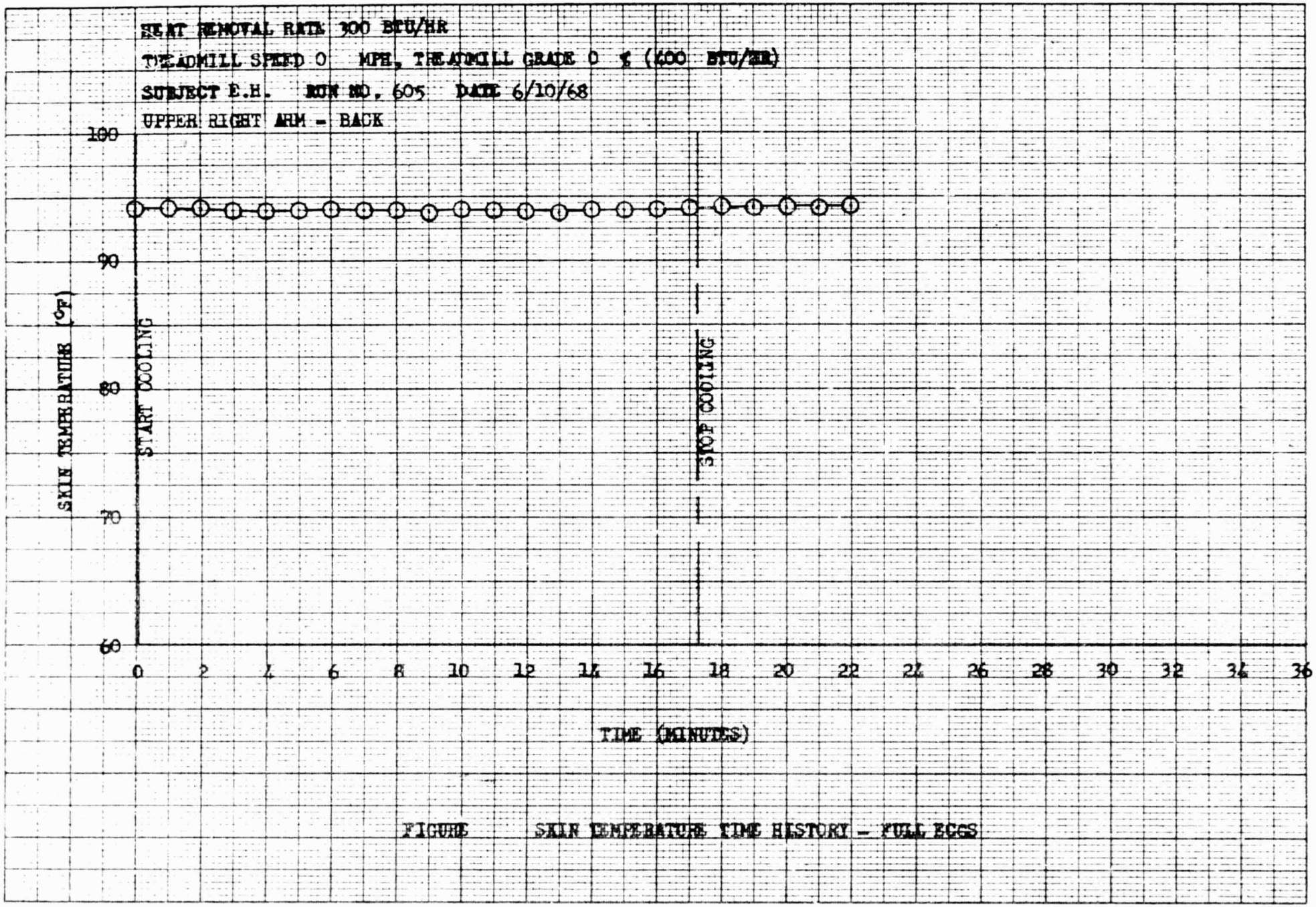


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL EGGS

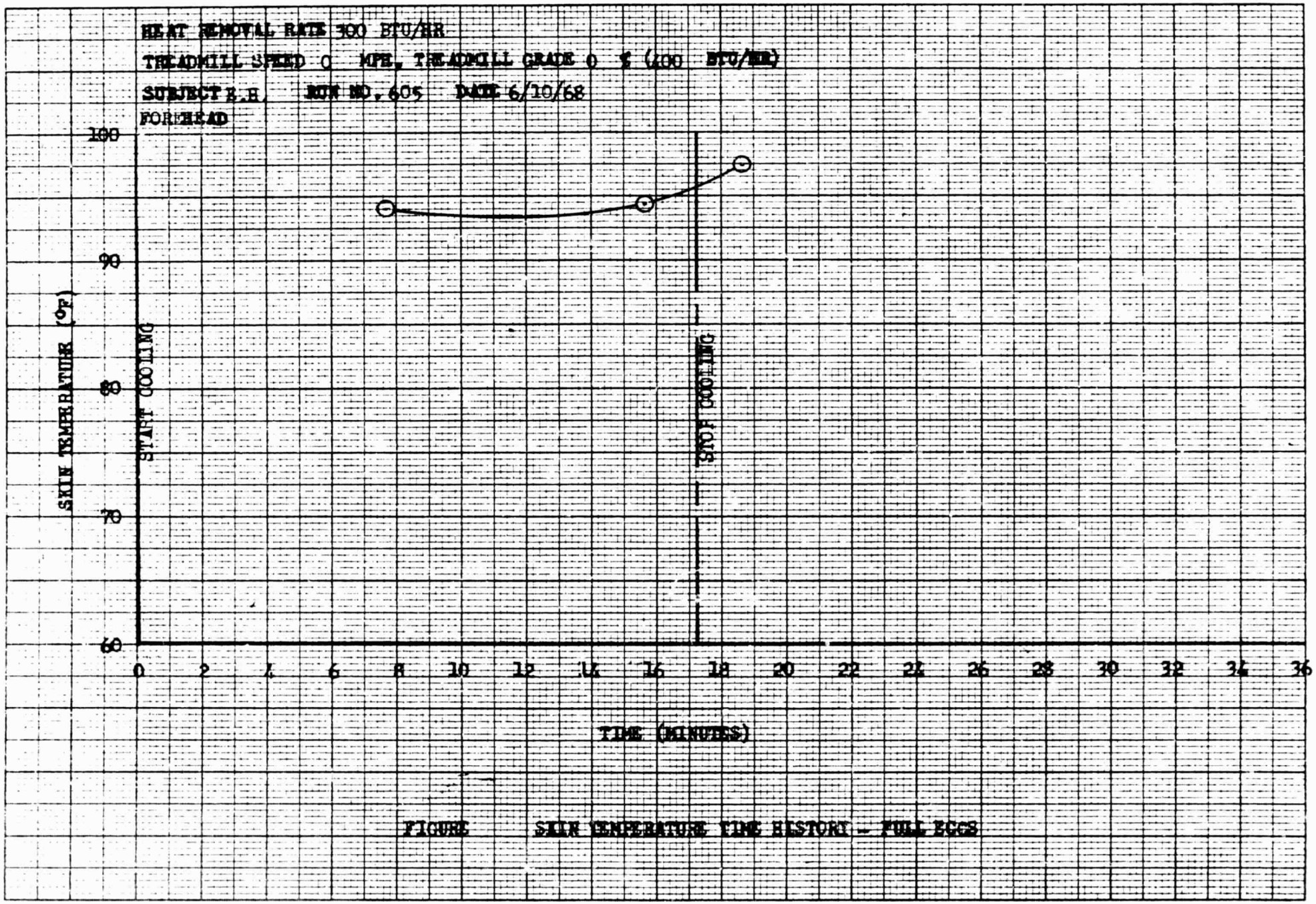


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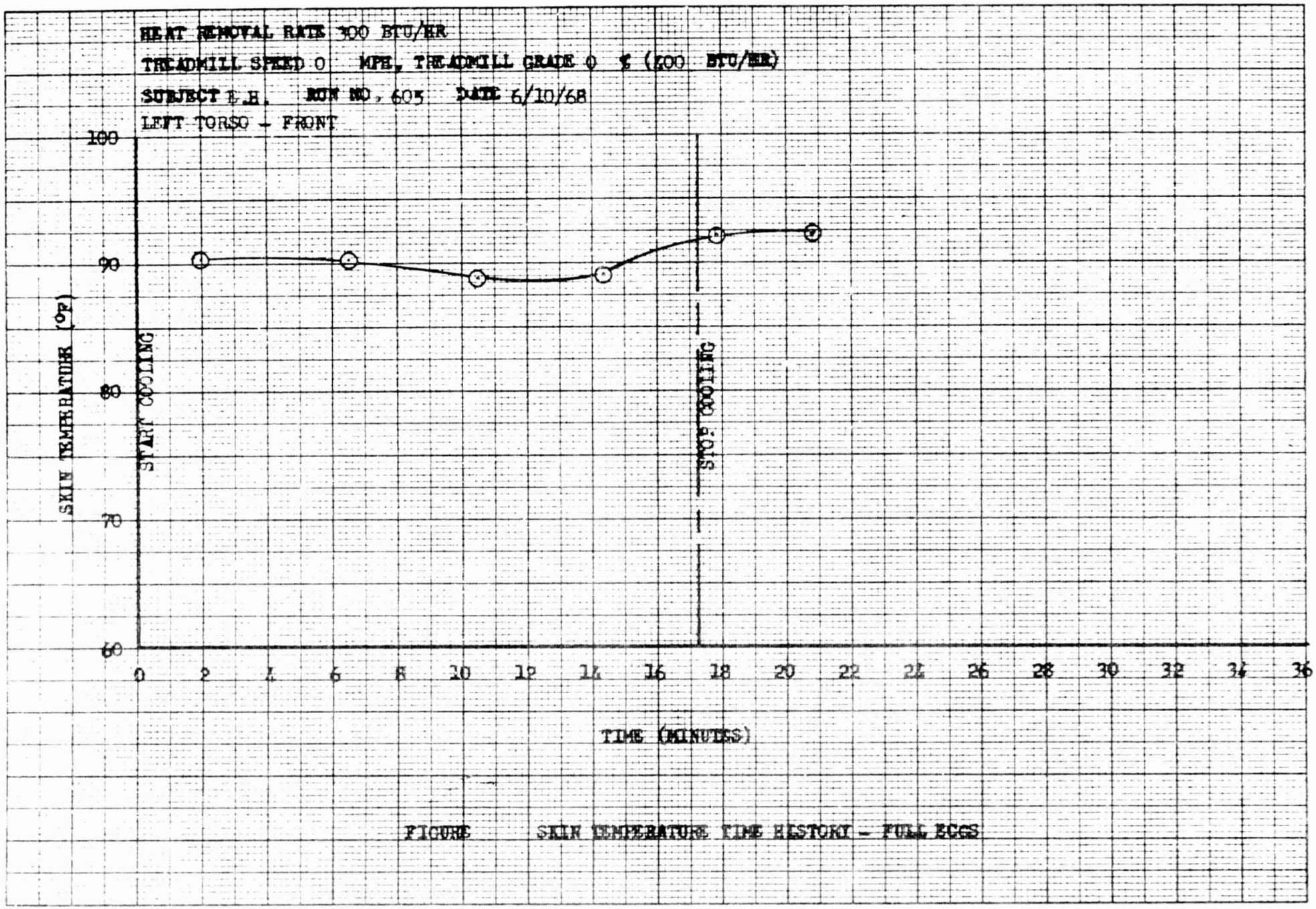


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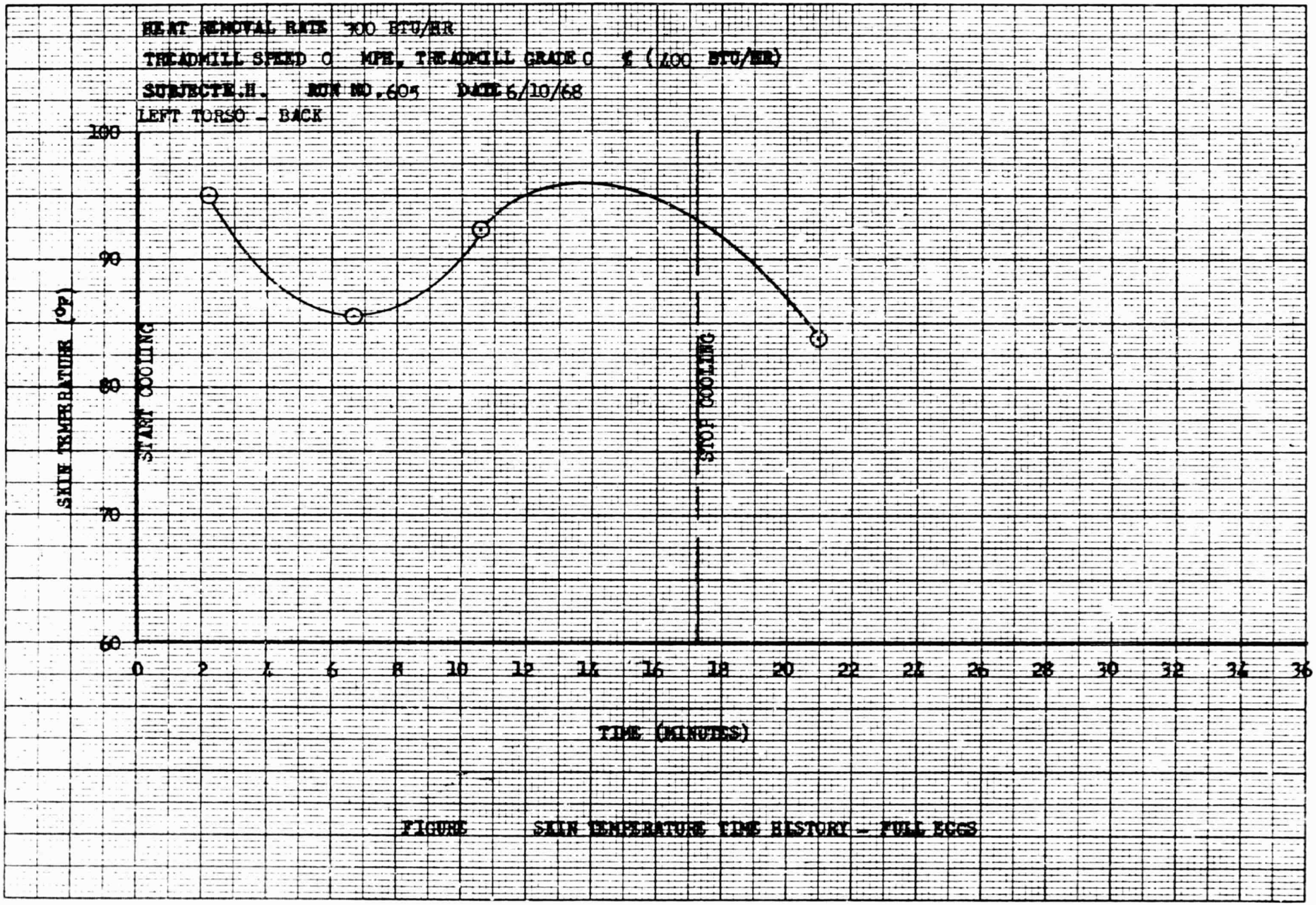


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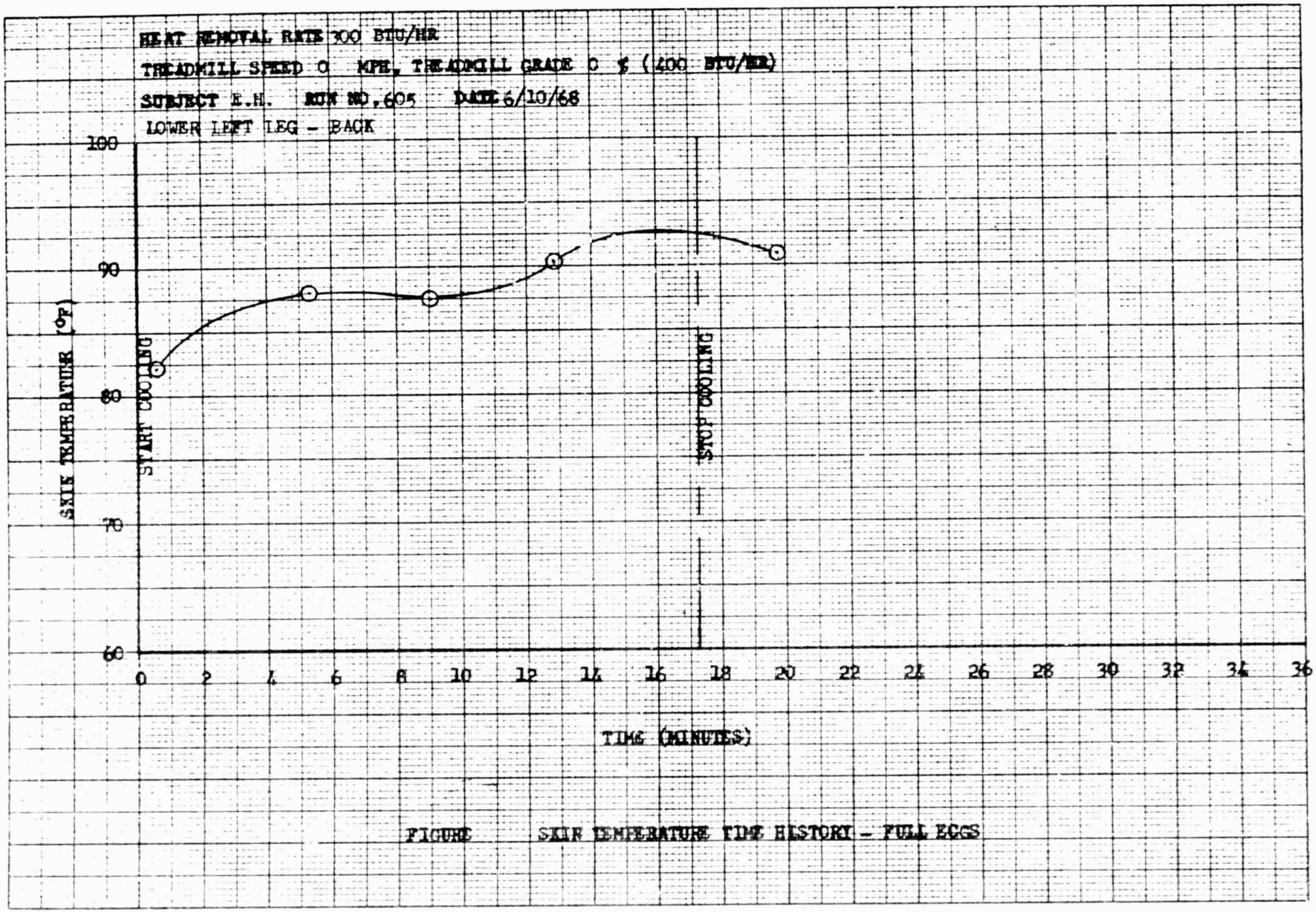


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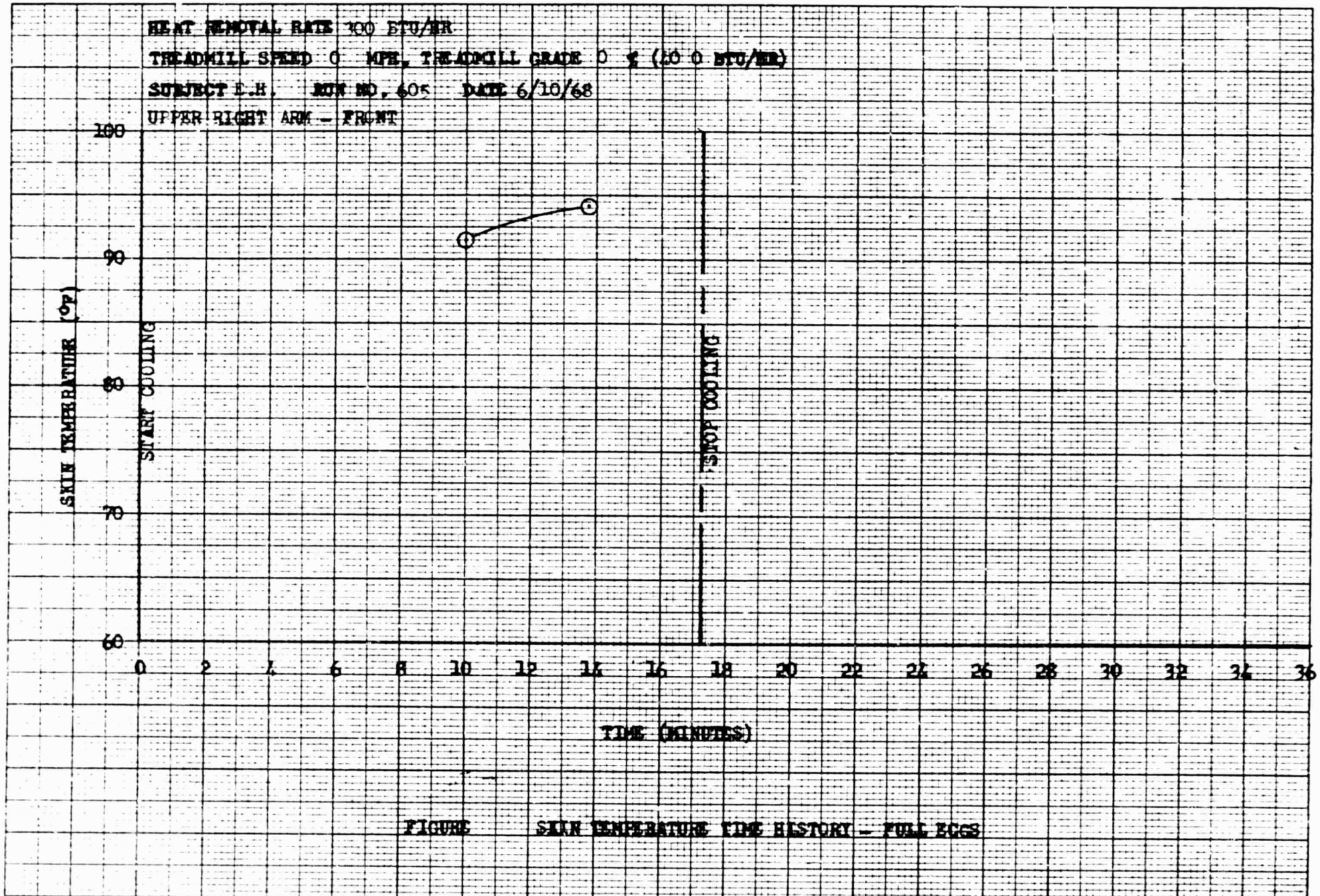


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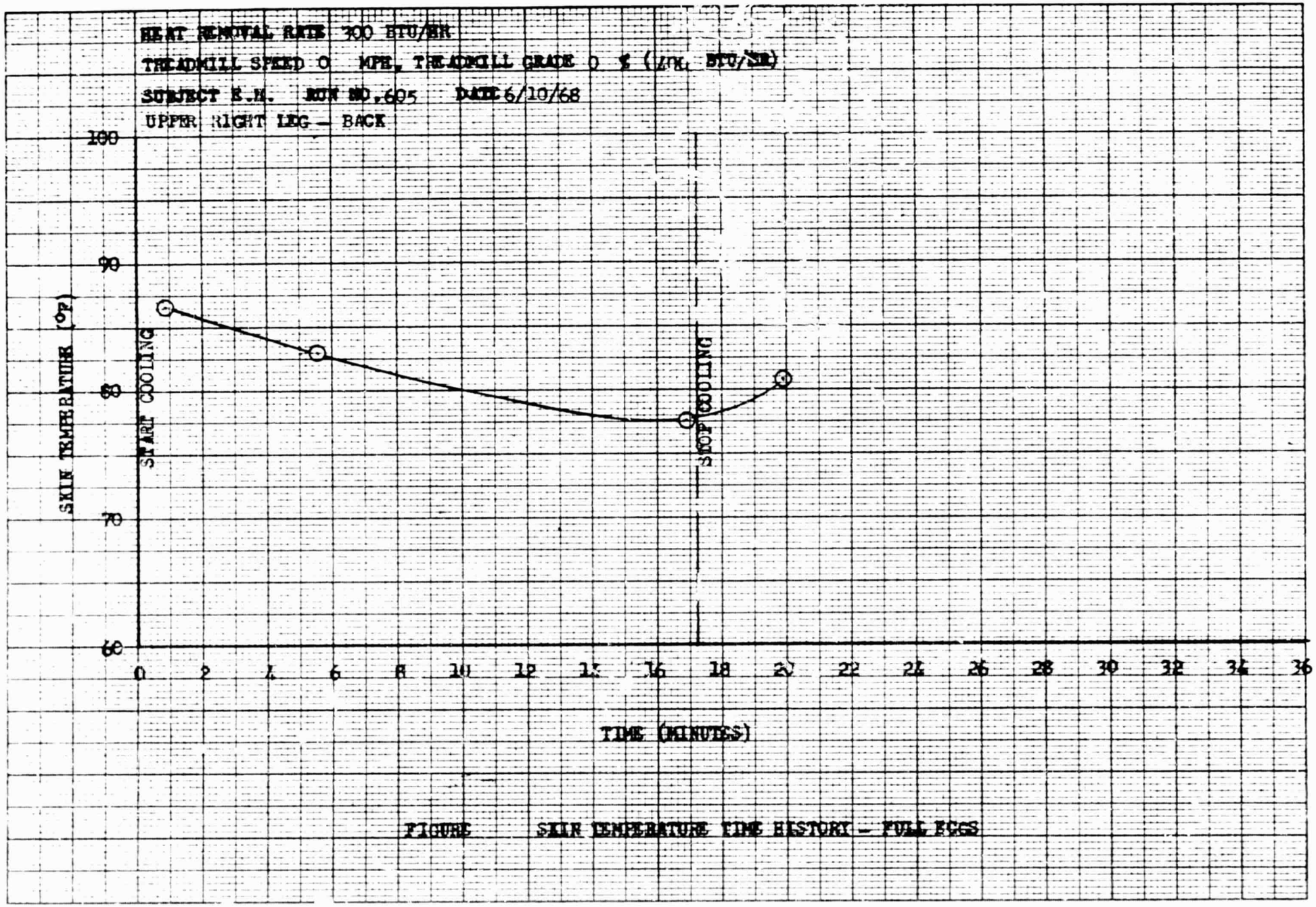


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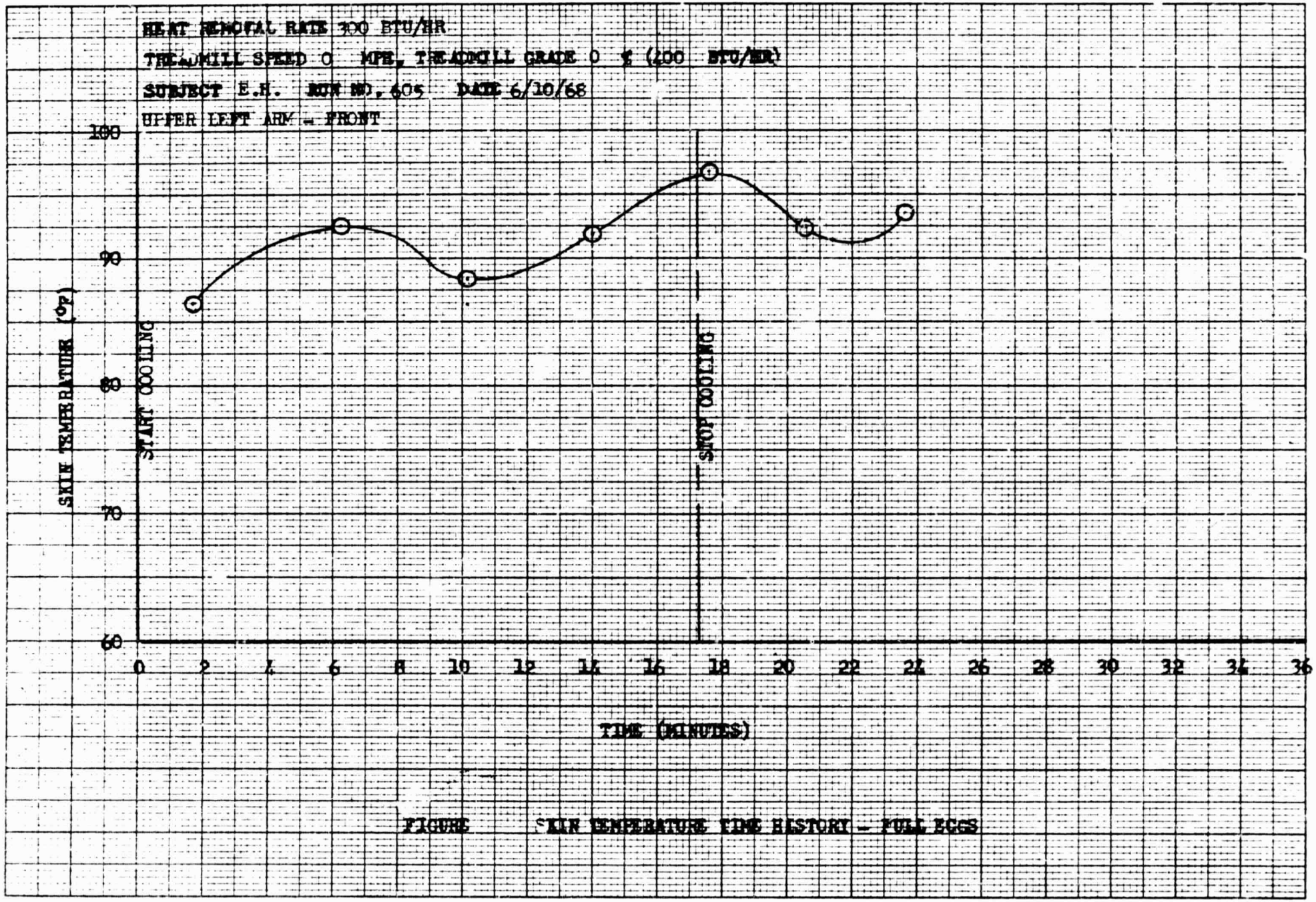


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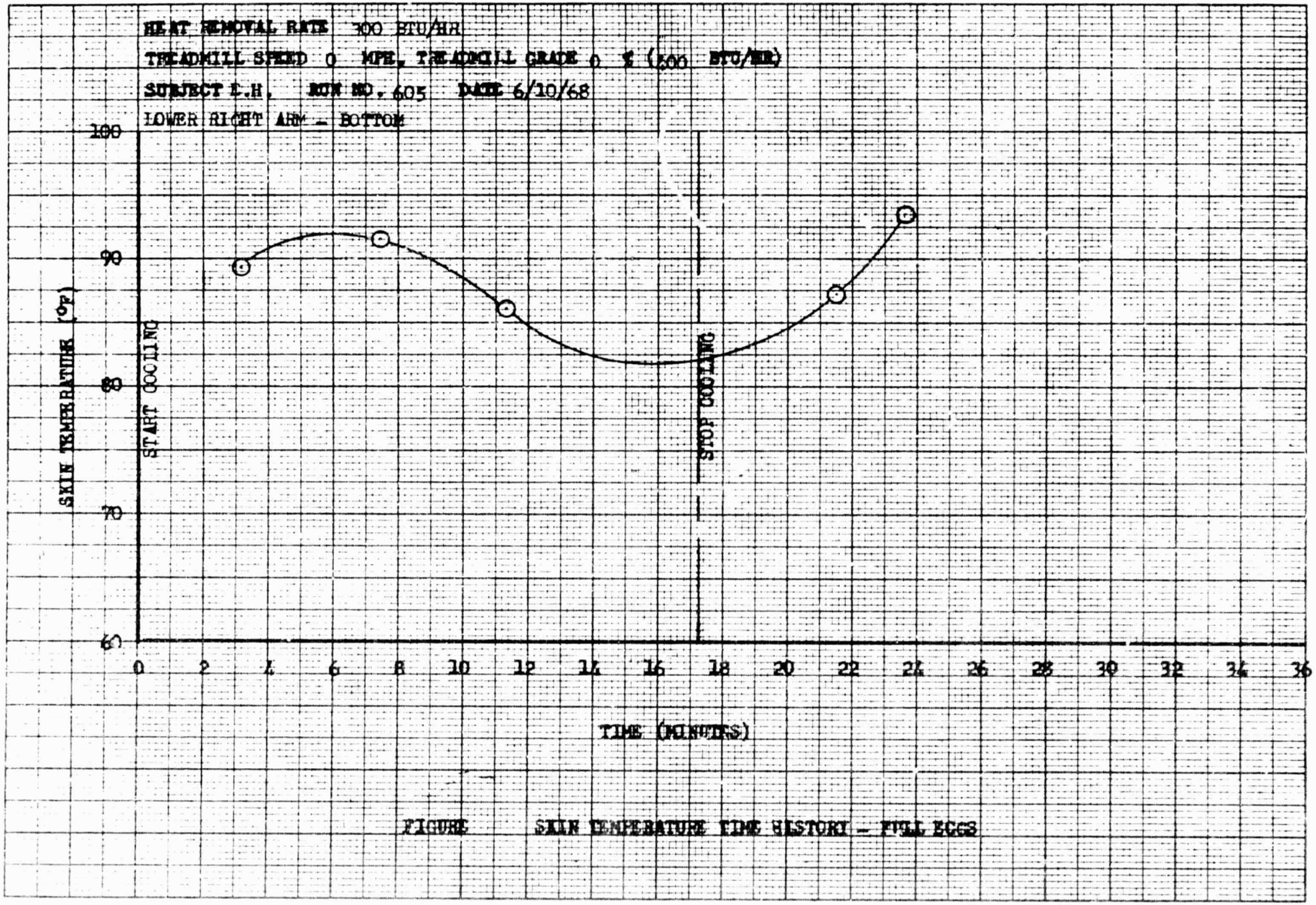


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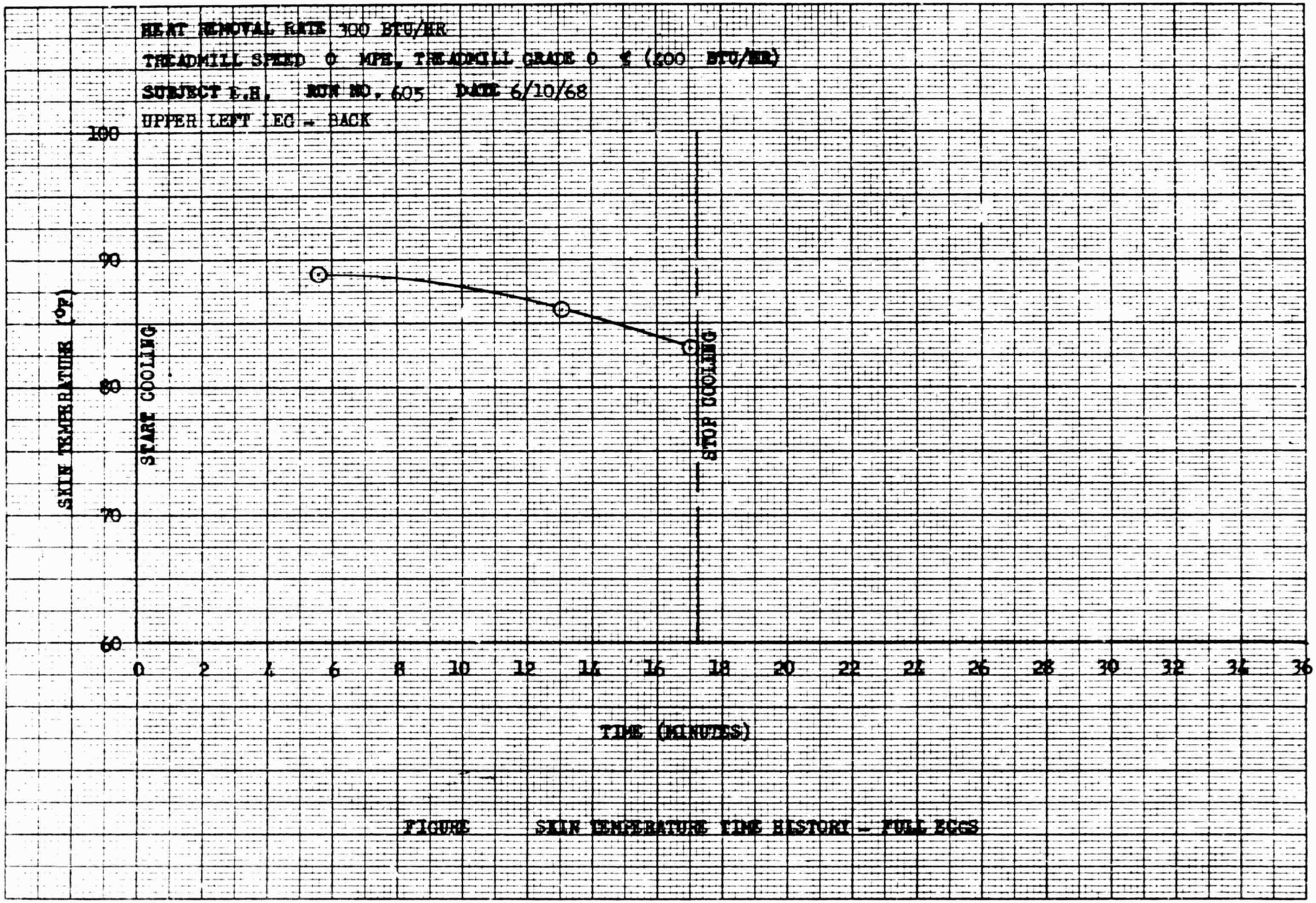


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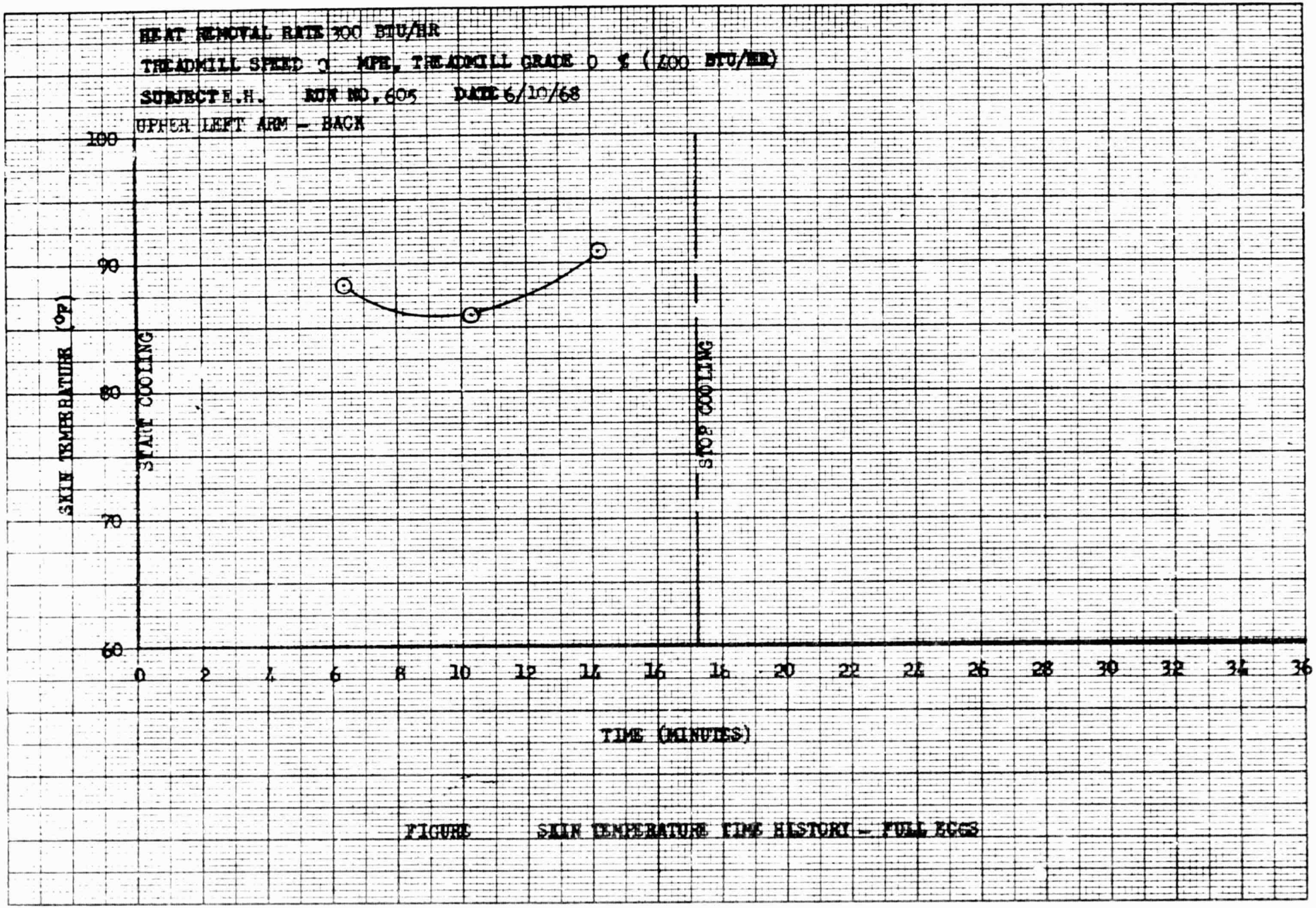


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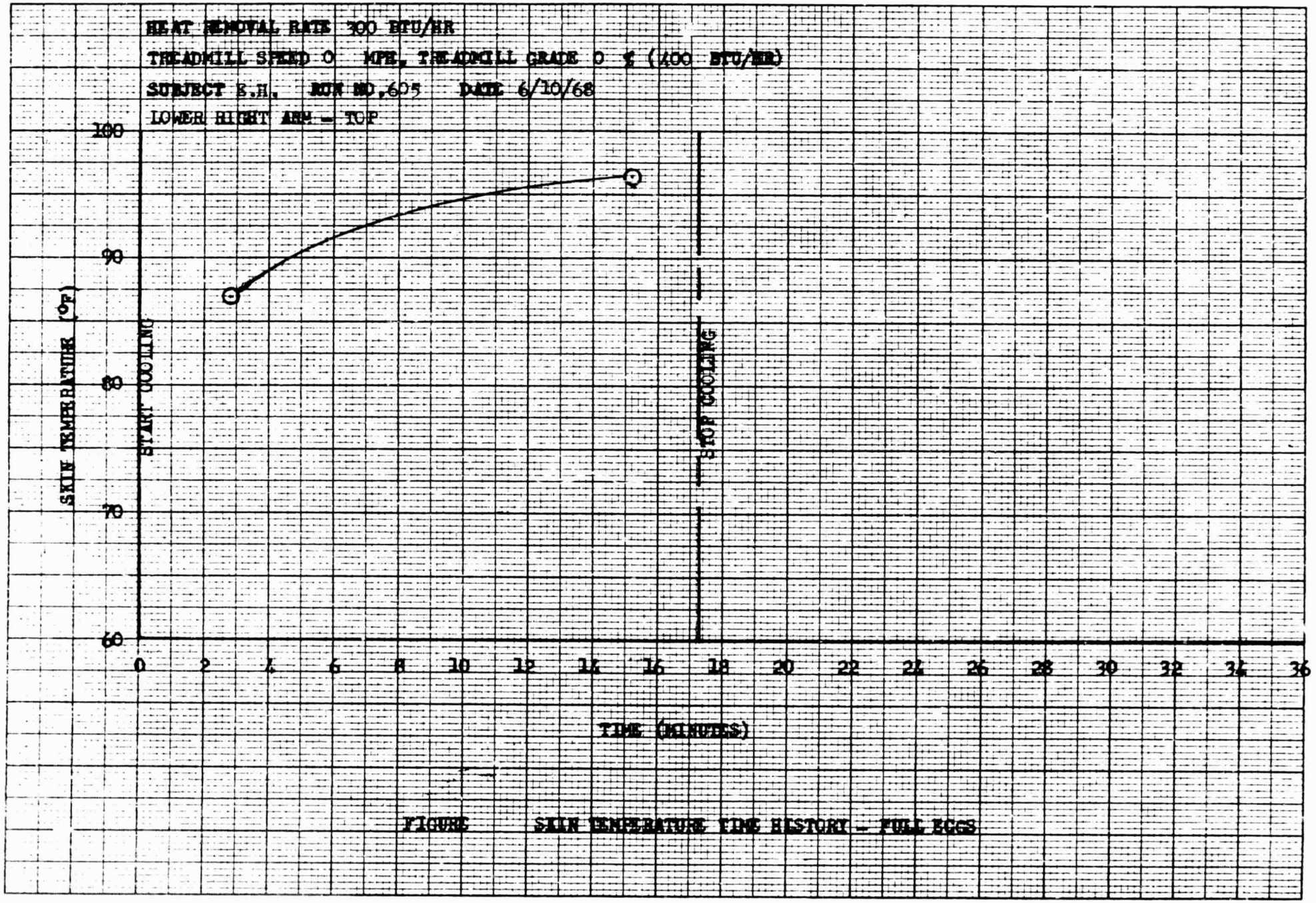


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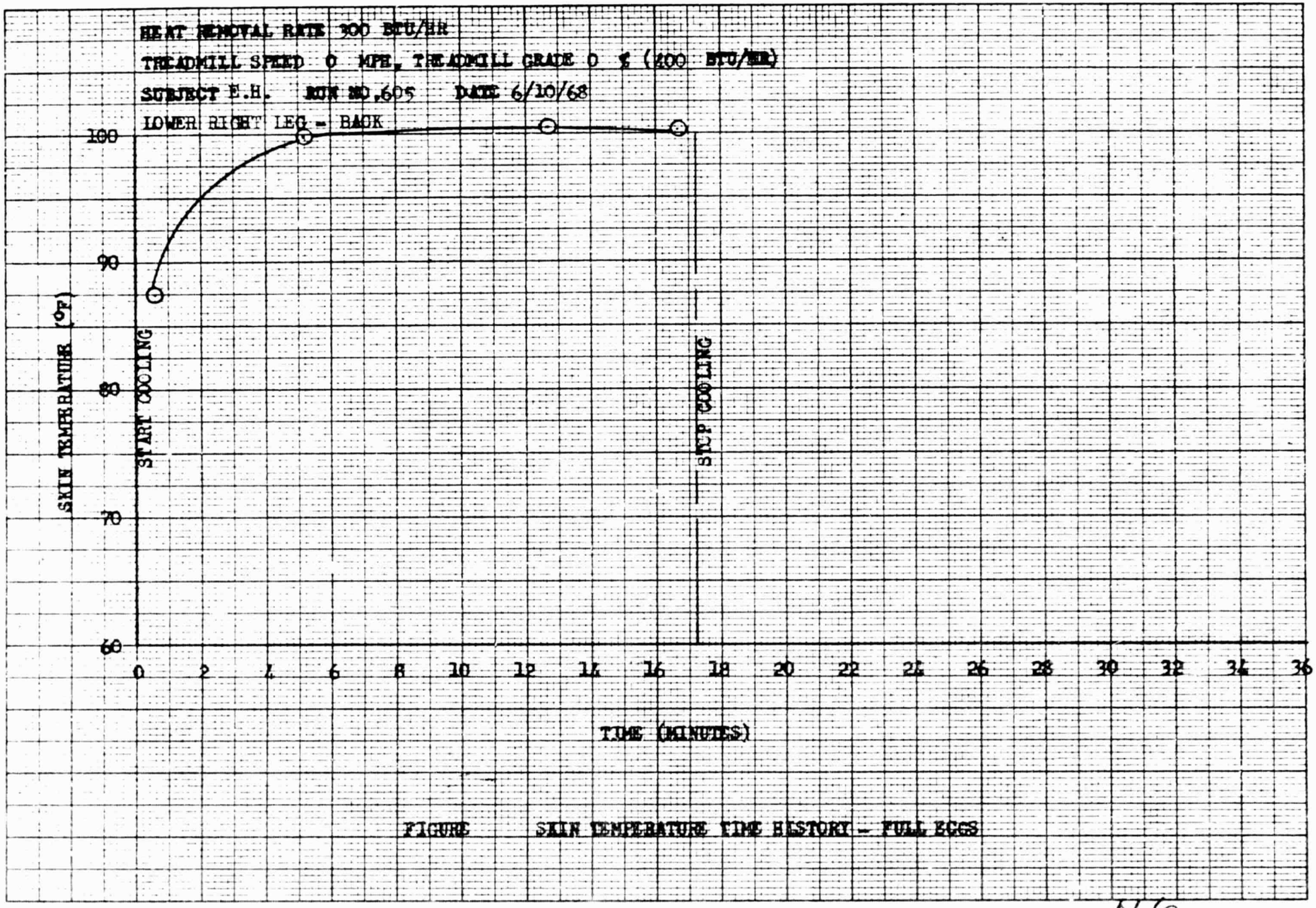


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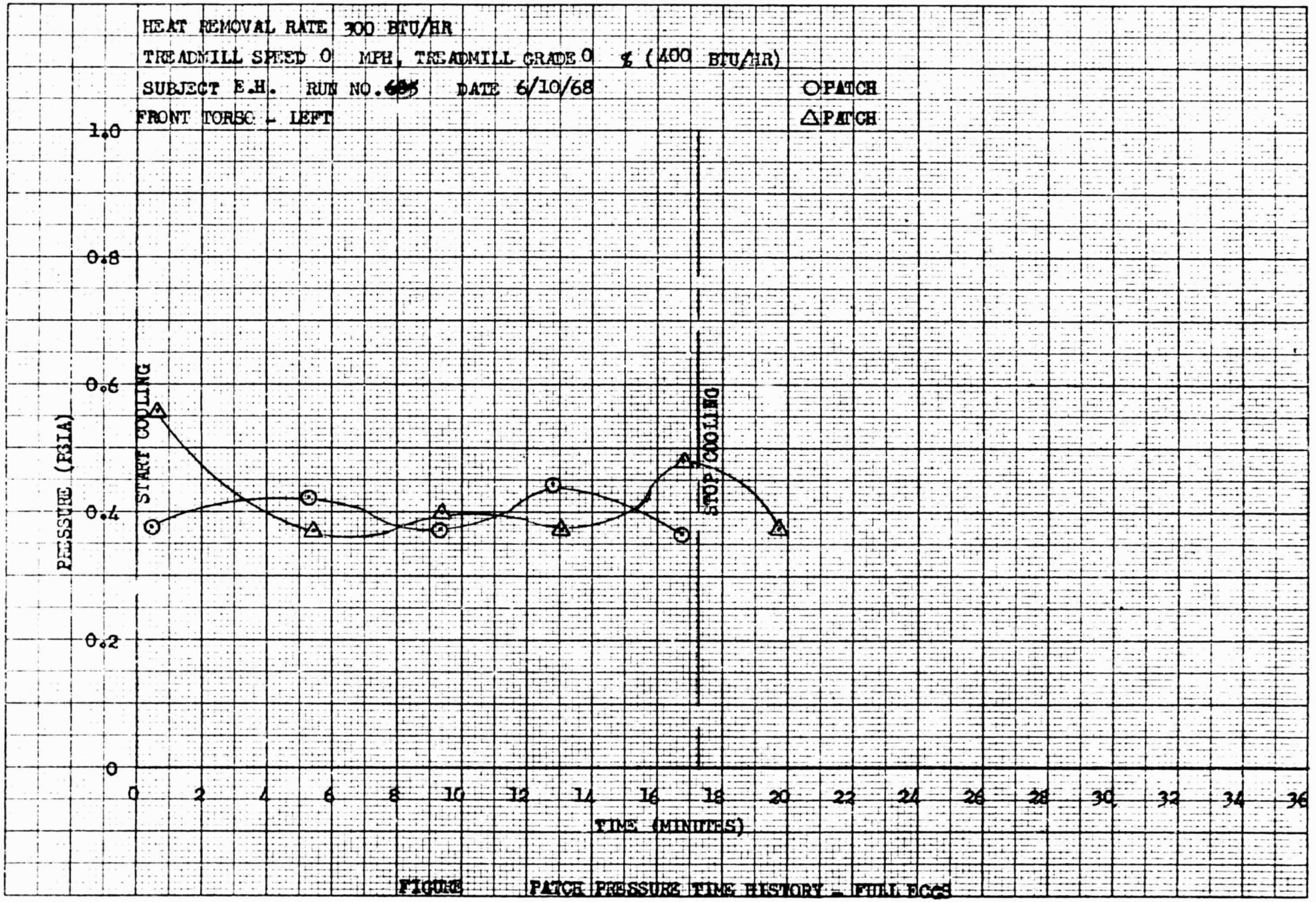


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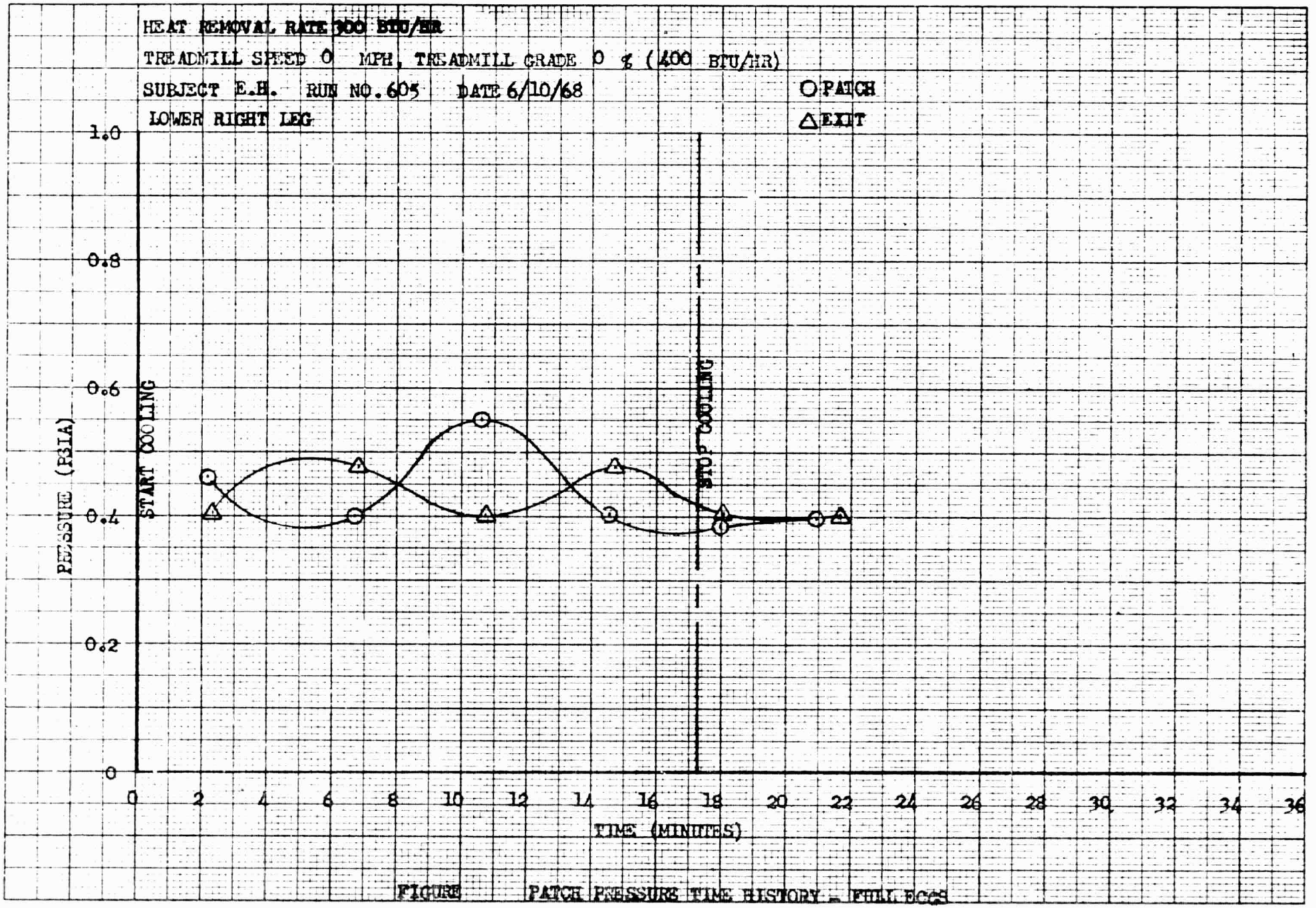


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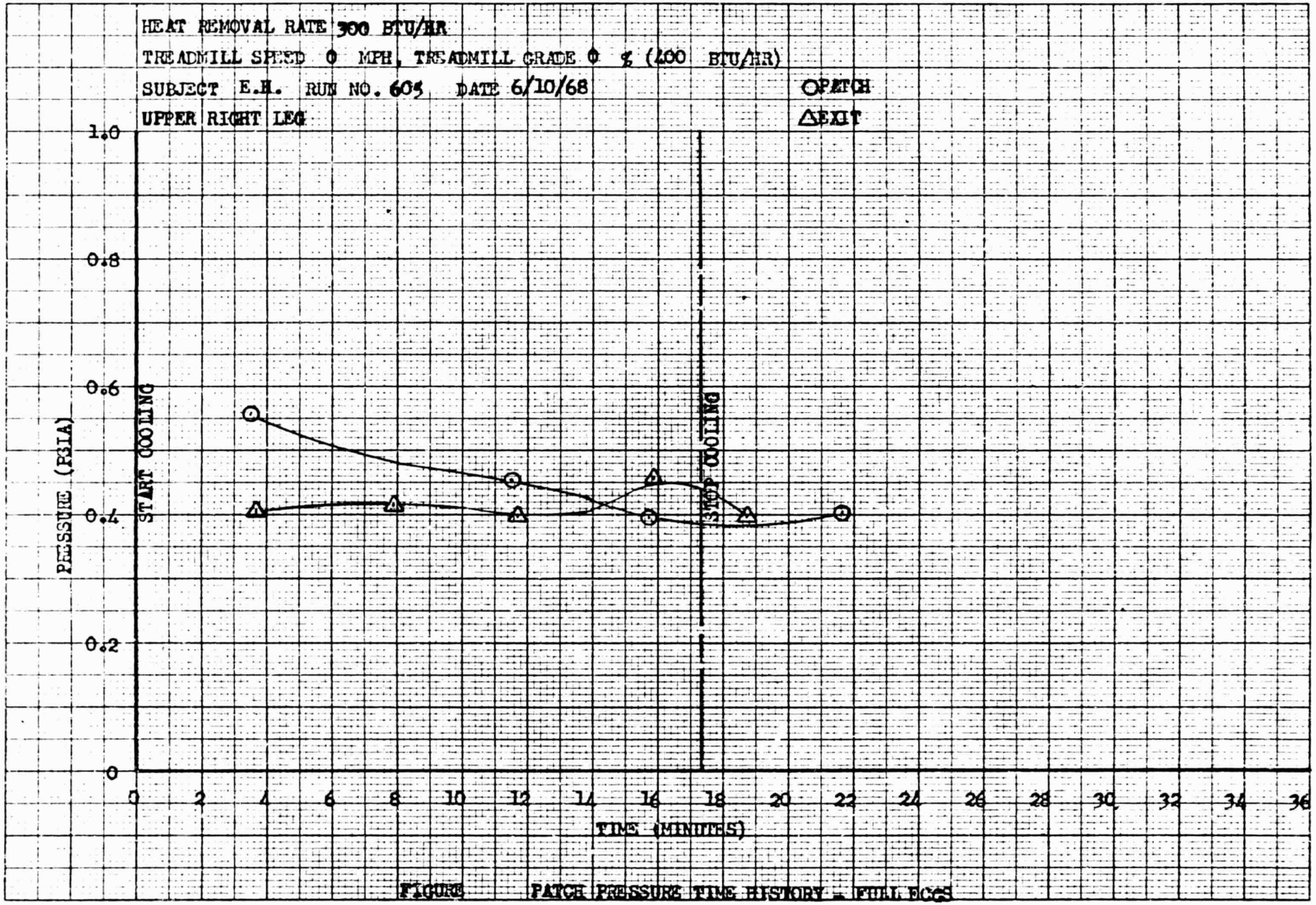


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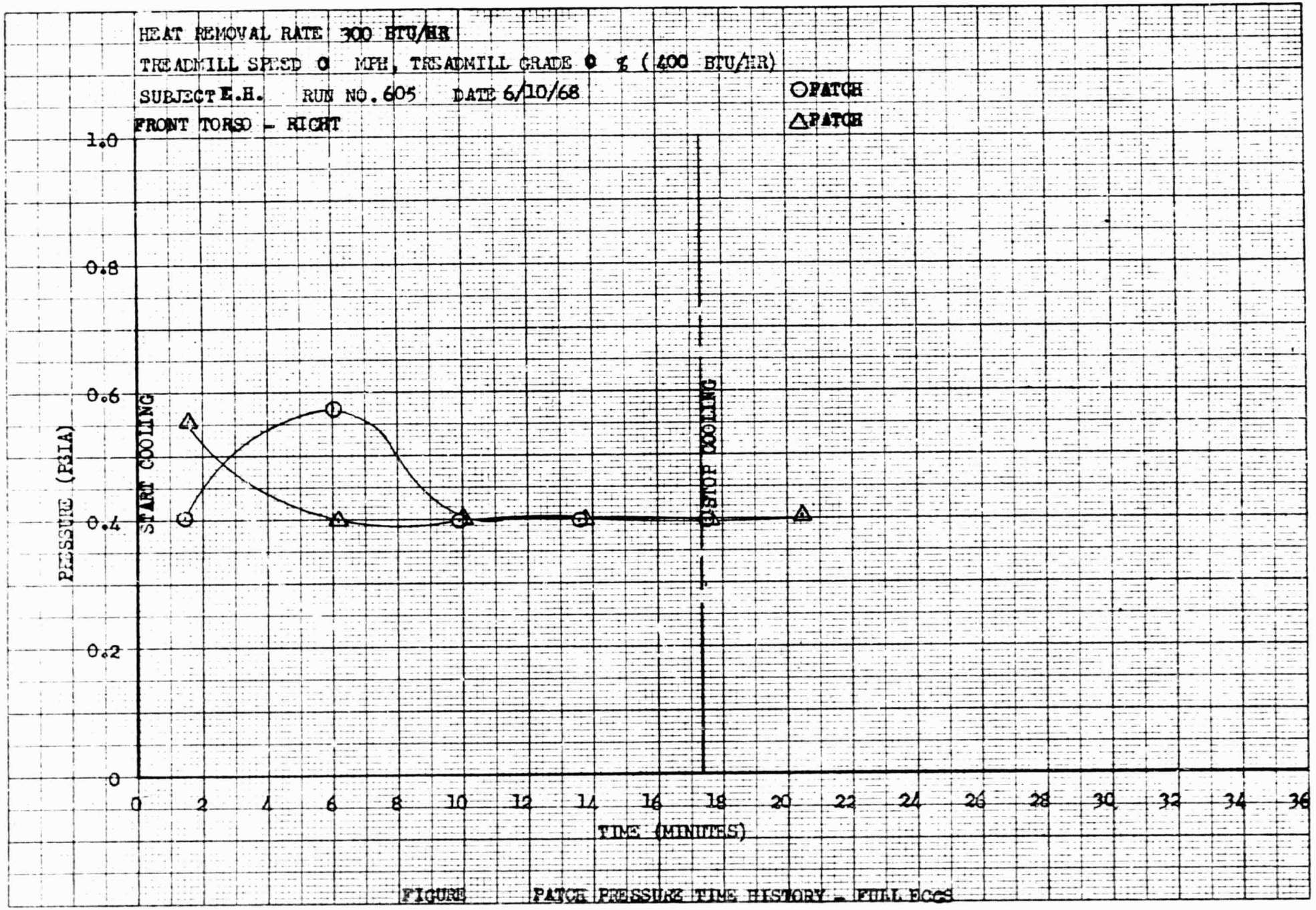


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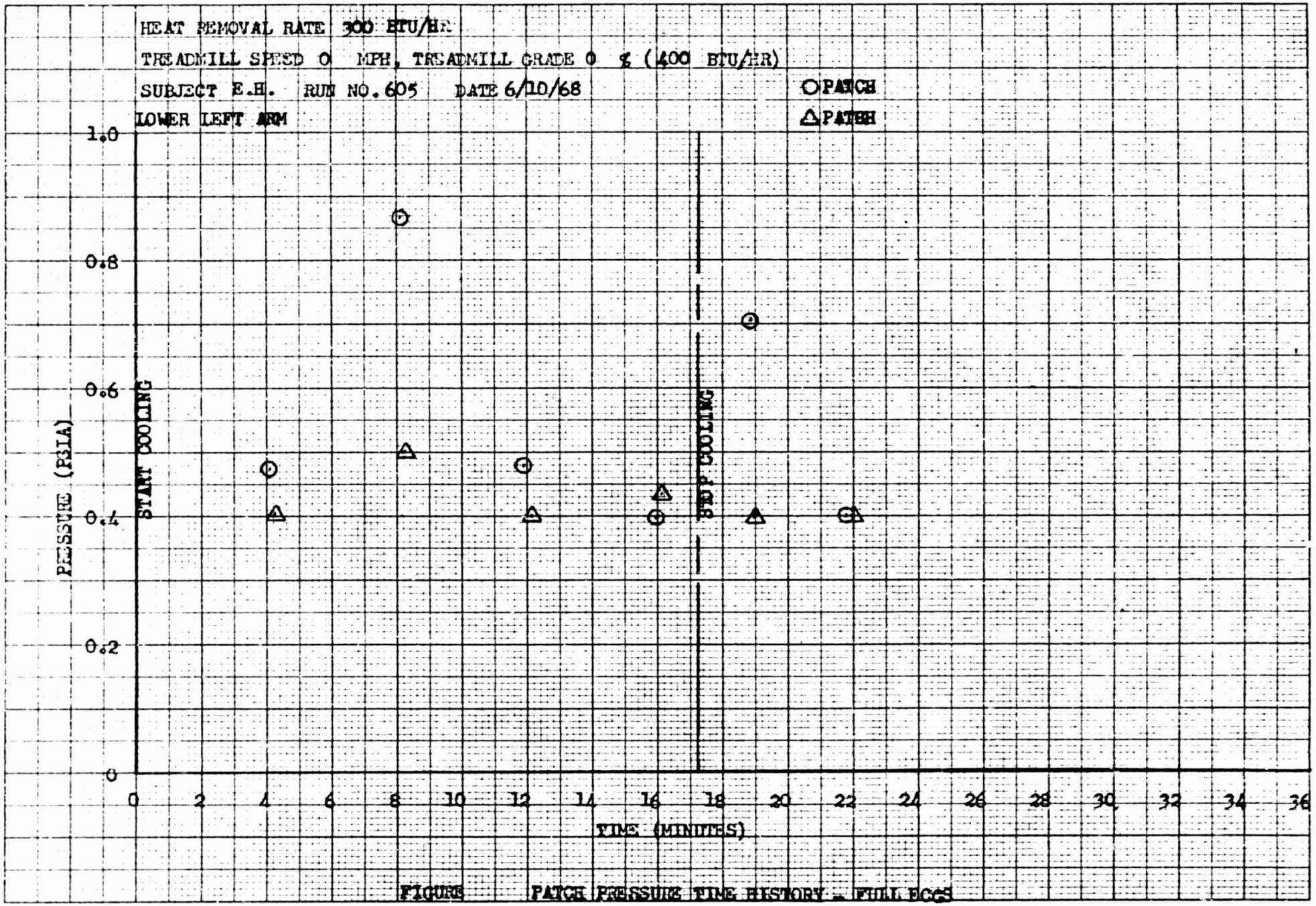


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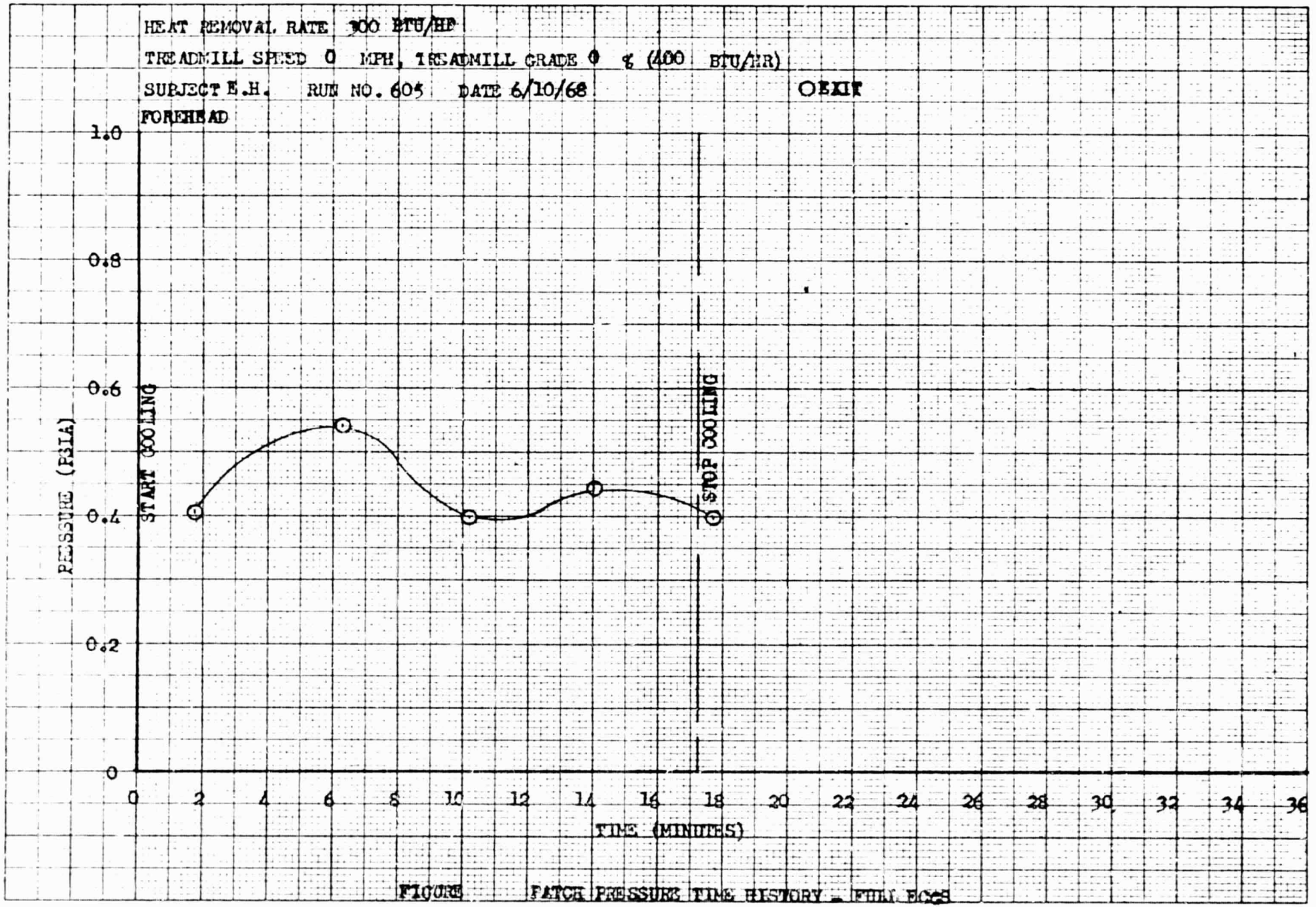


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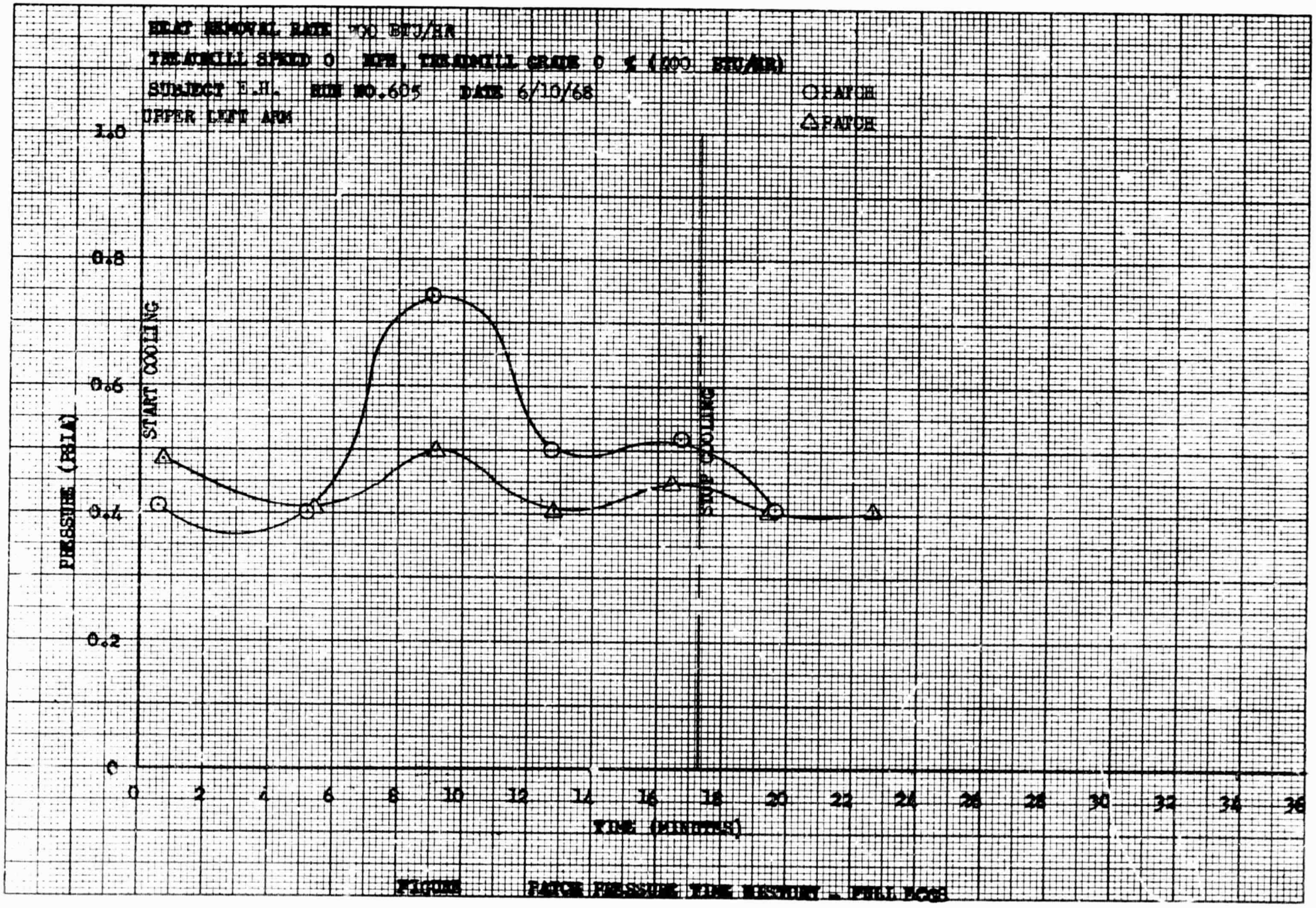


FIGURE FAFOR PRESSURE VERSUS TIME HISTORY - FULL SCALE

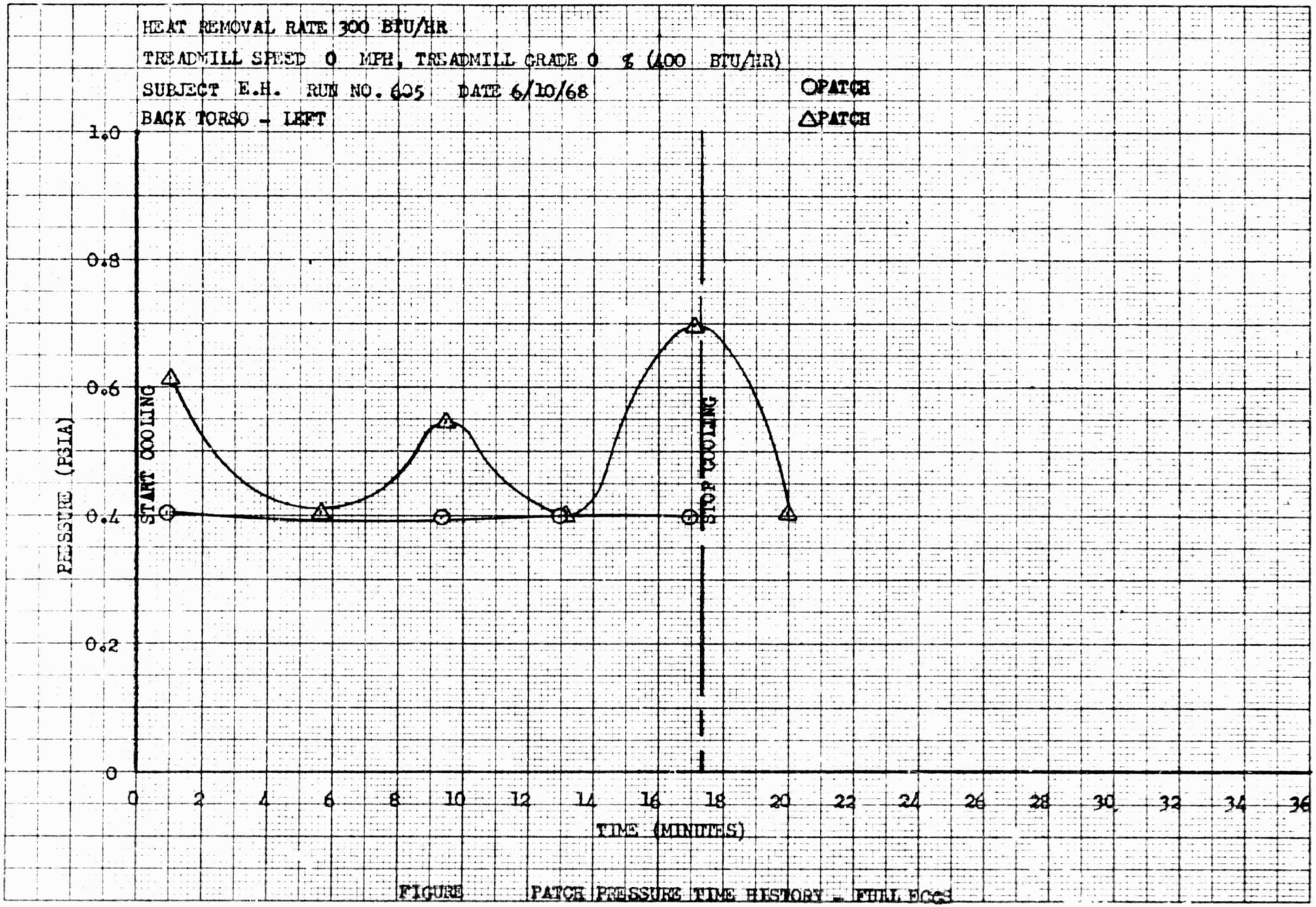


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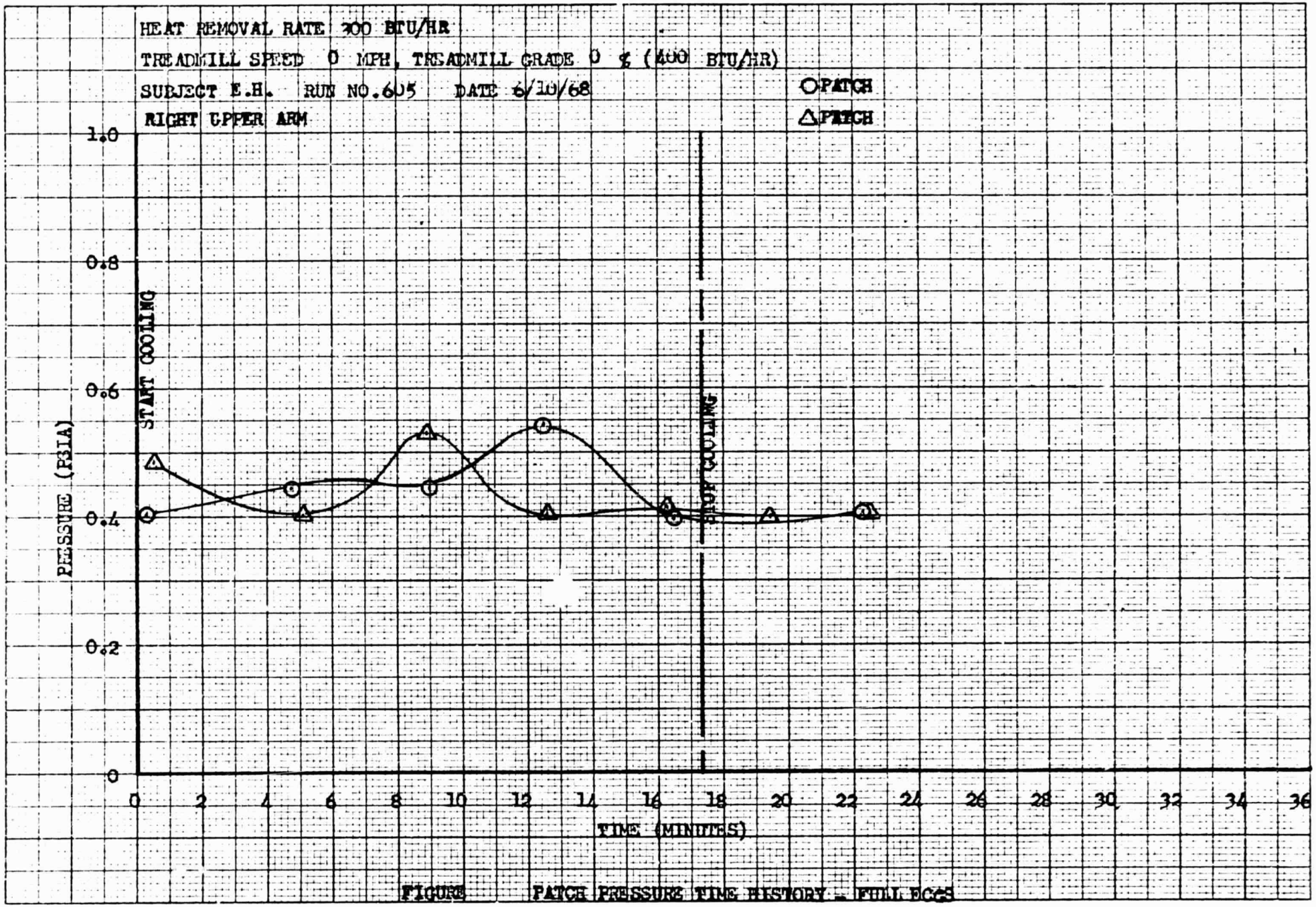


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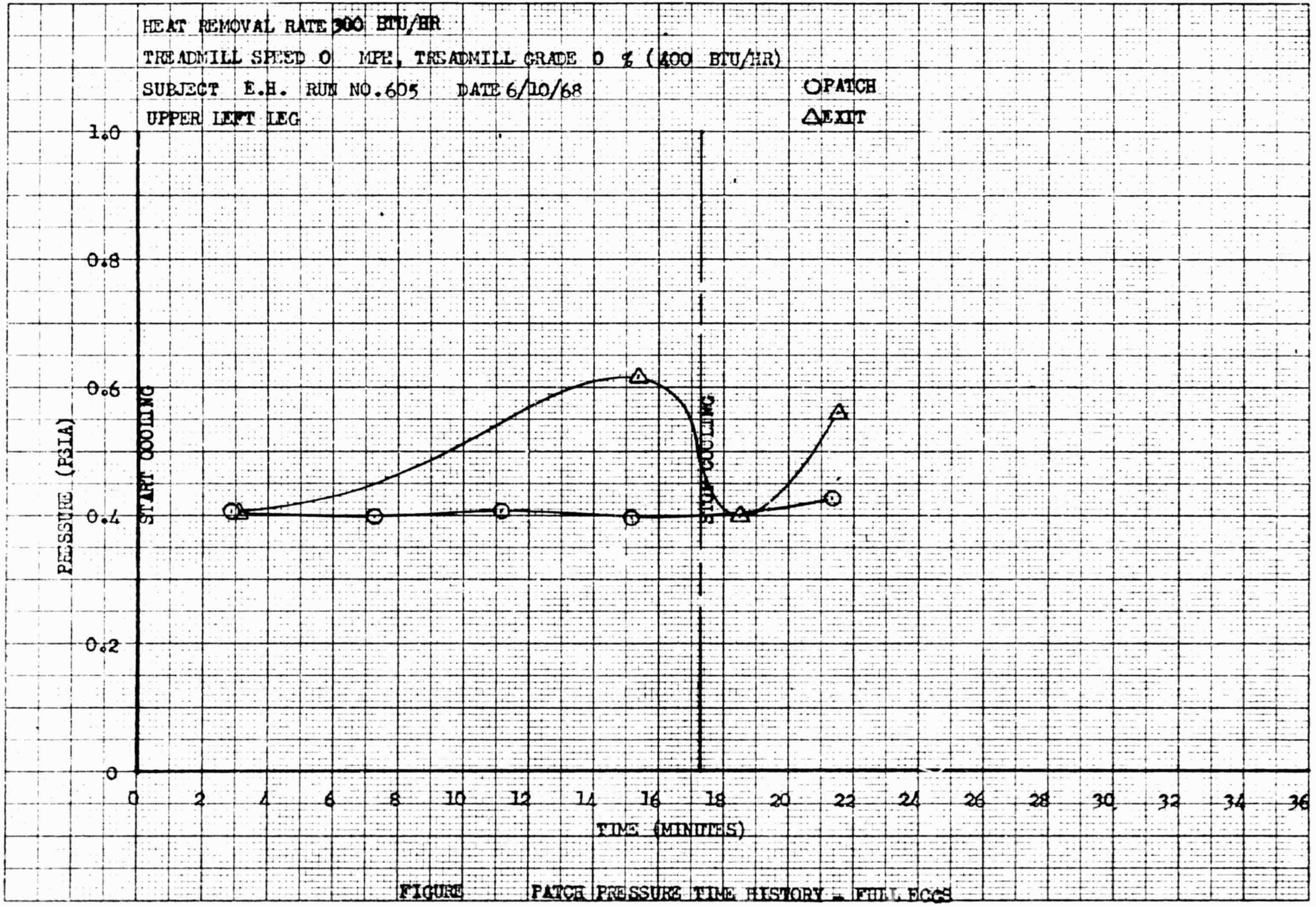


FIGURE PATCH PRESSURE TIME HISTORY - FULL ECGS

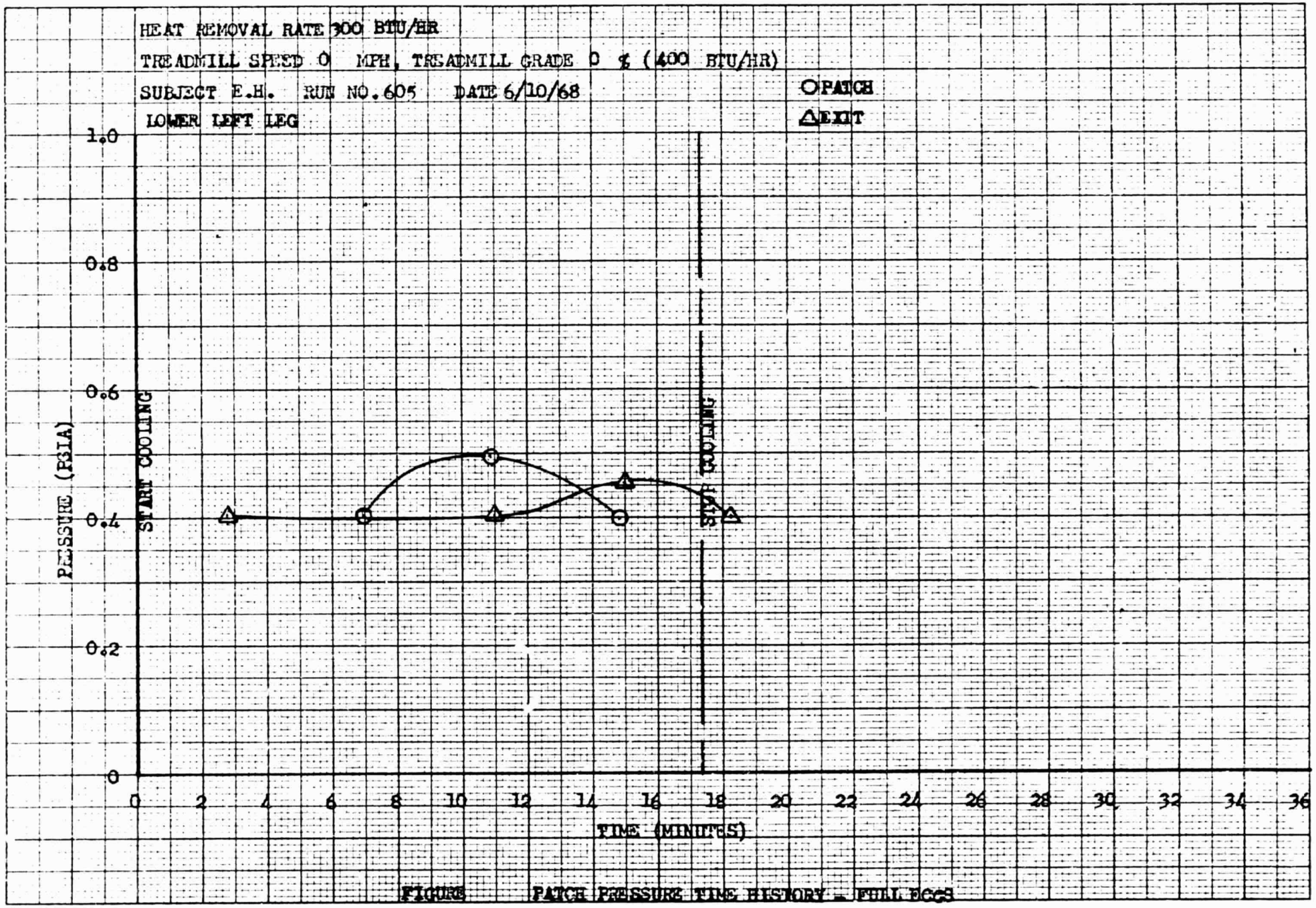


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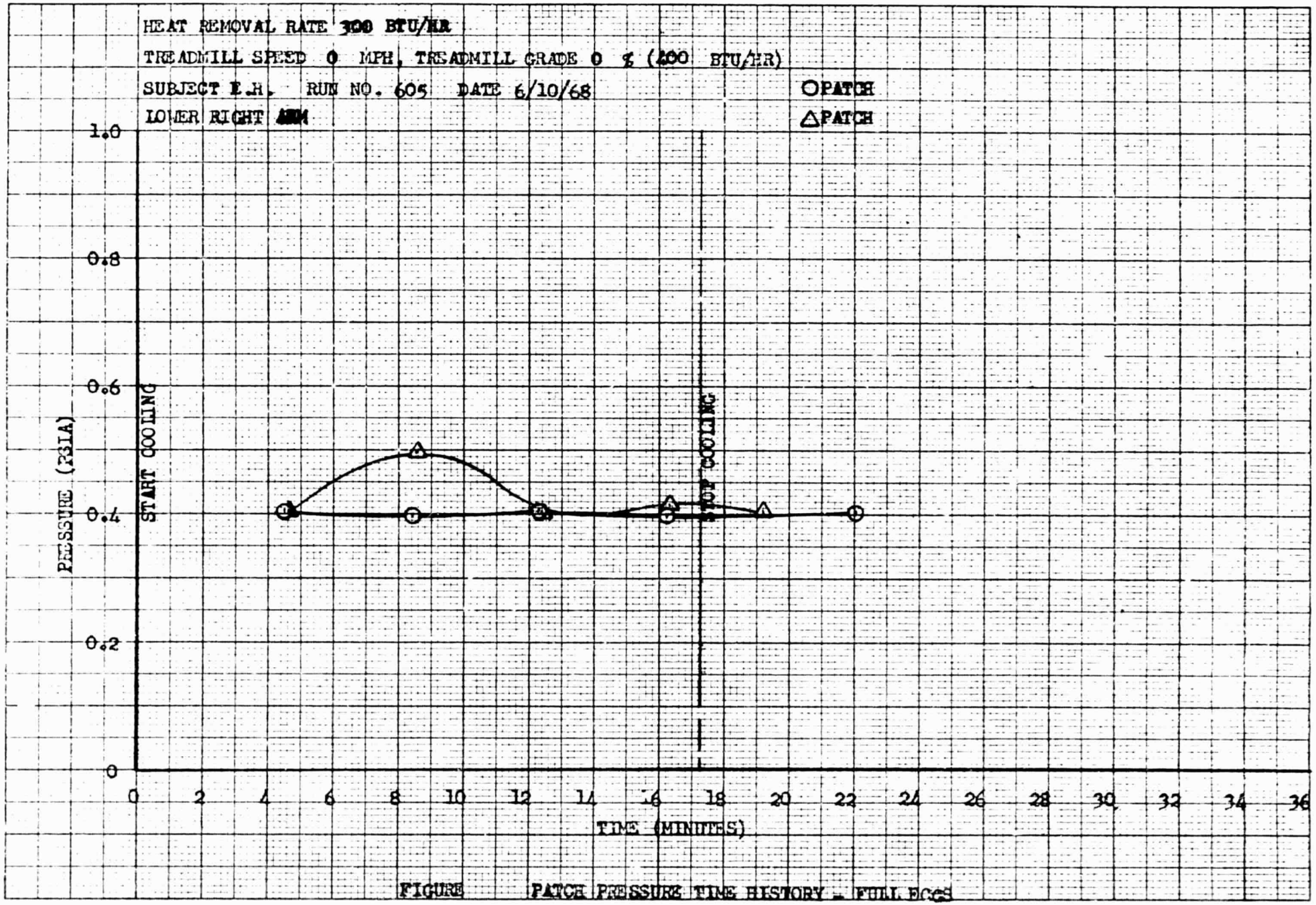


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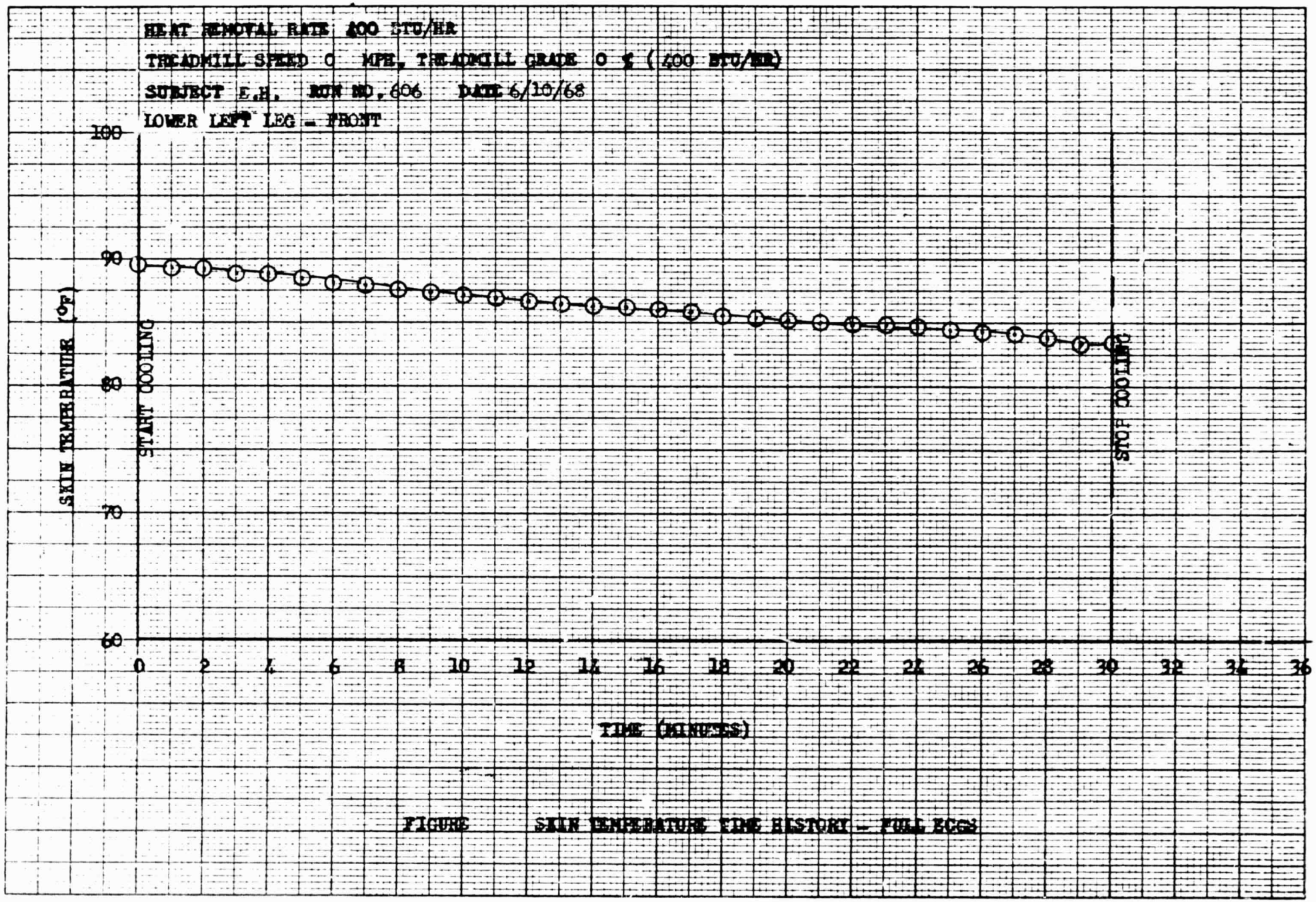


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECSS

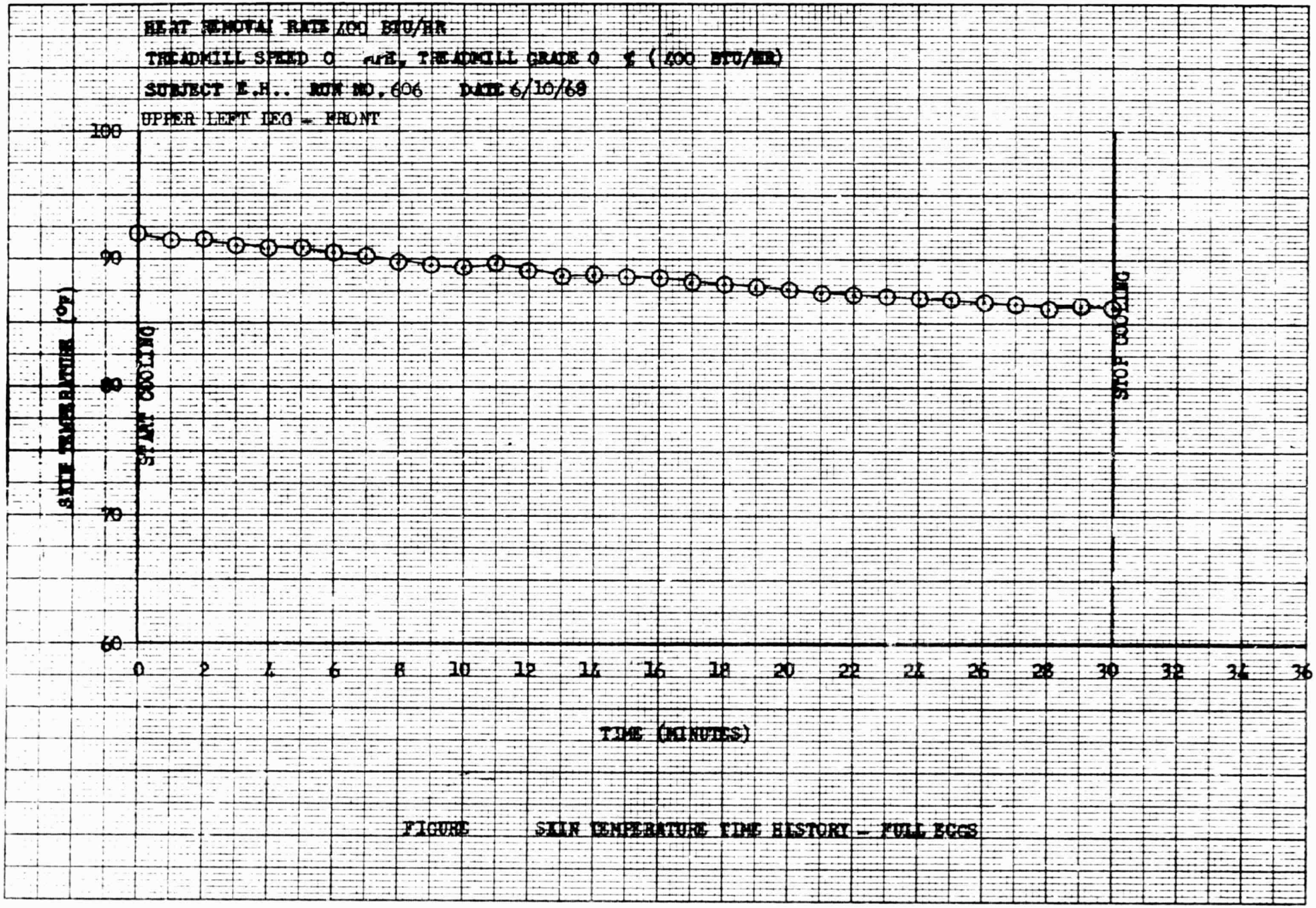


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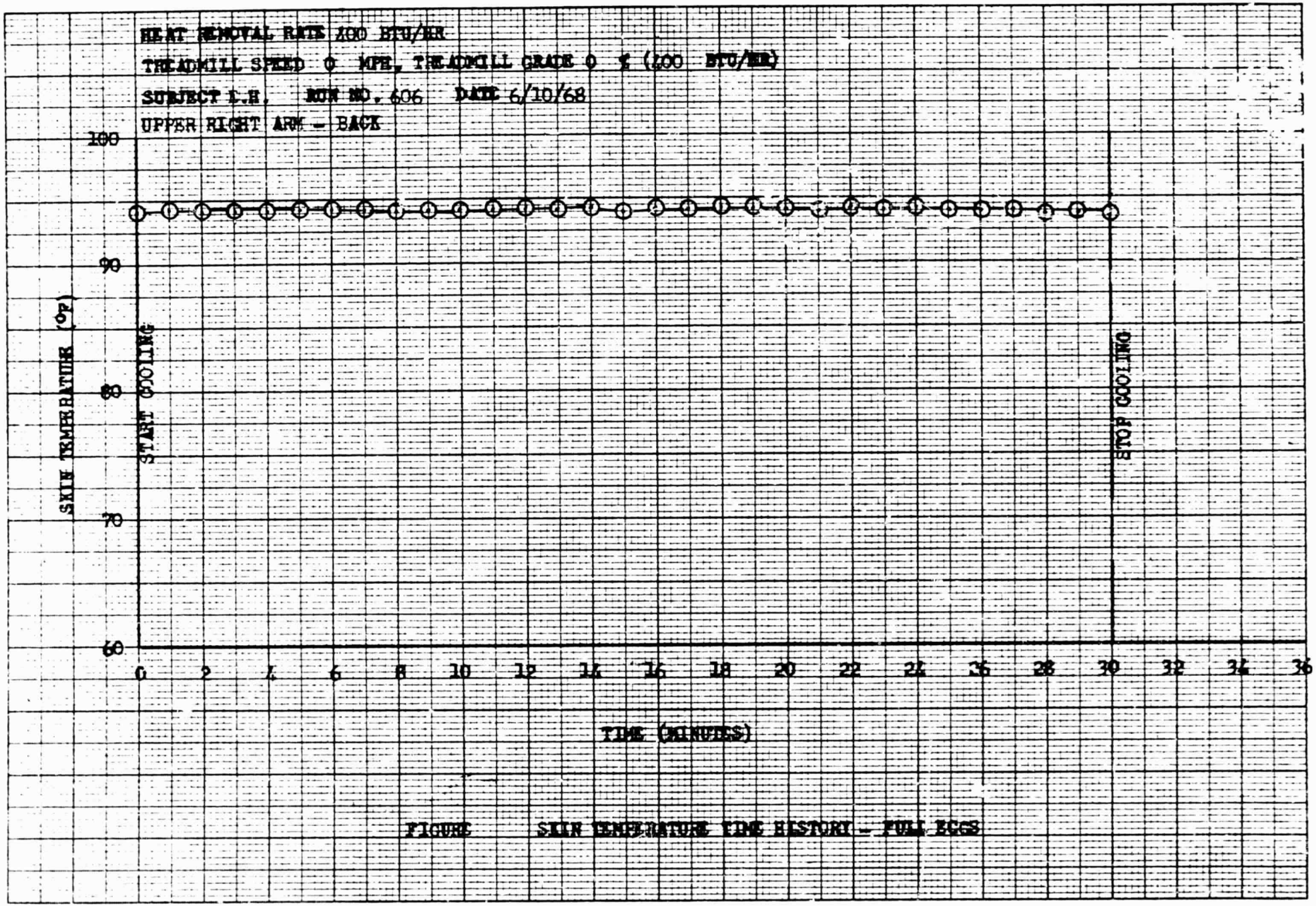


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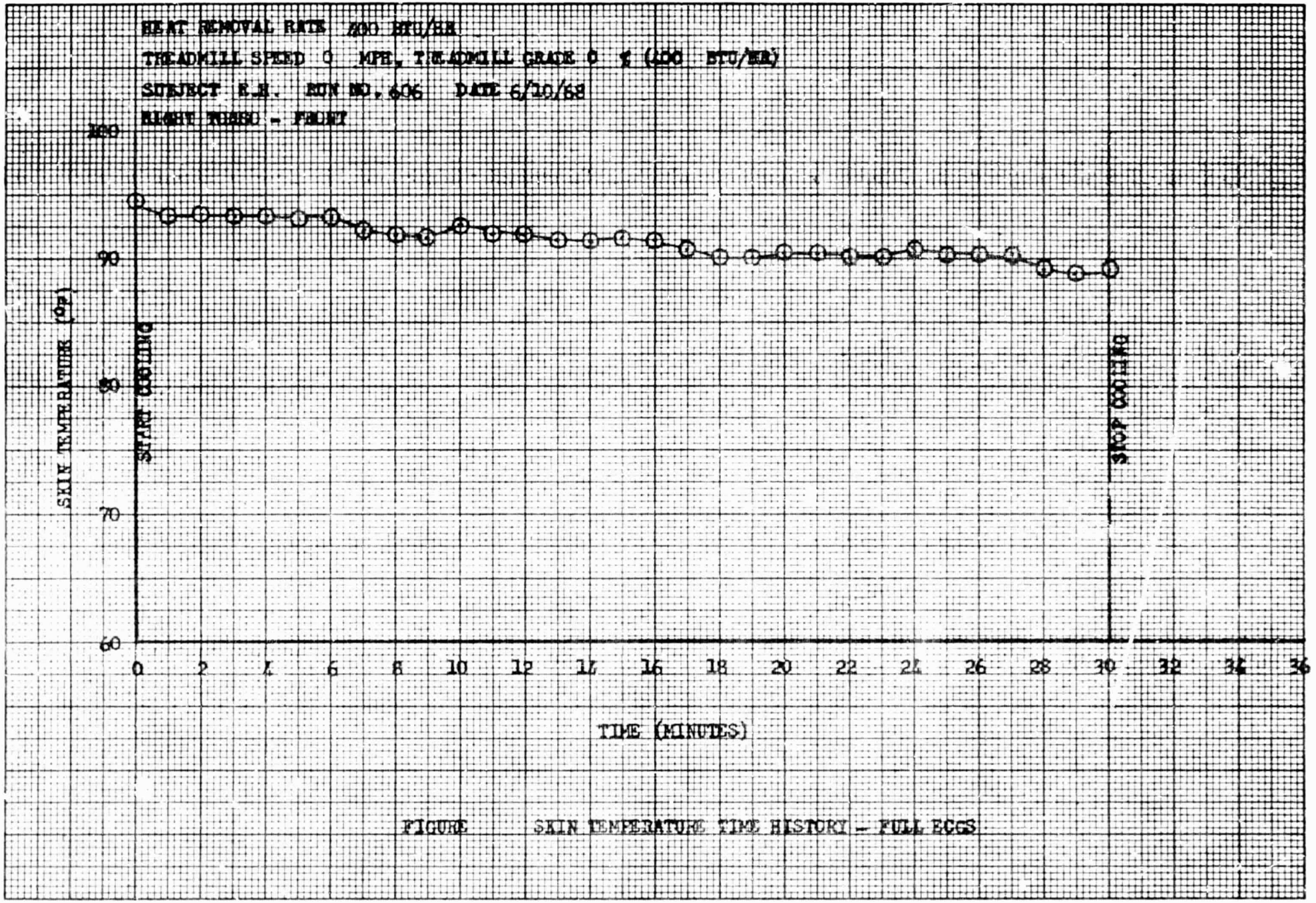


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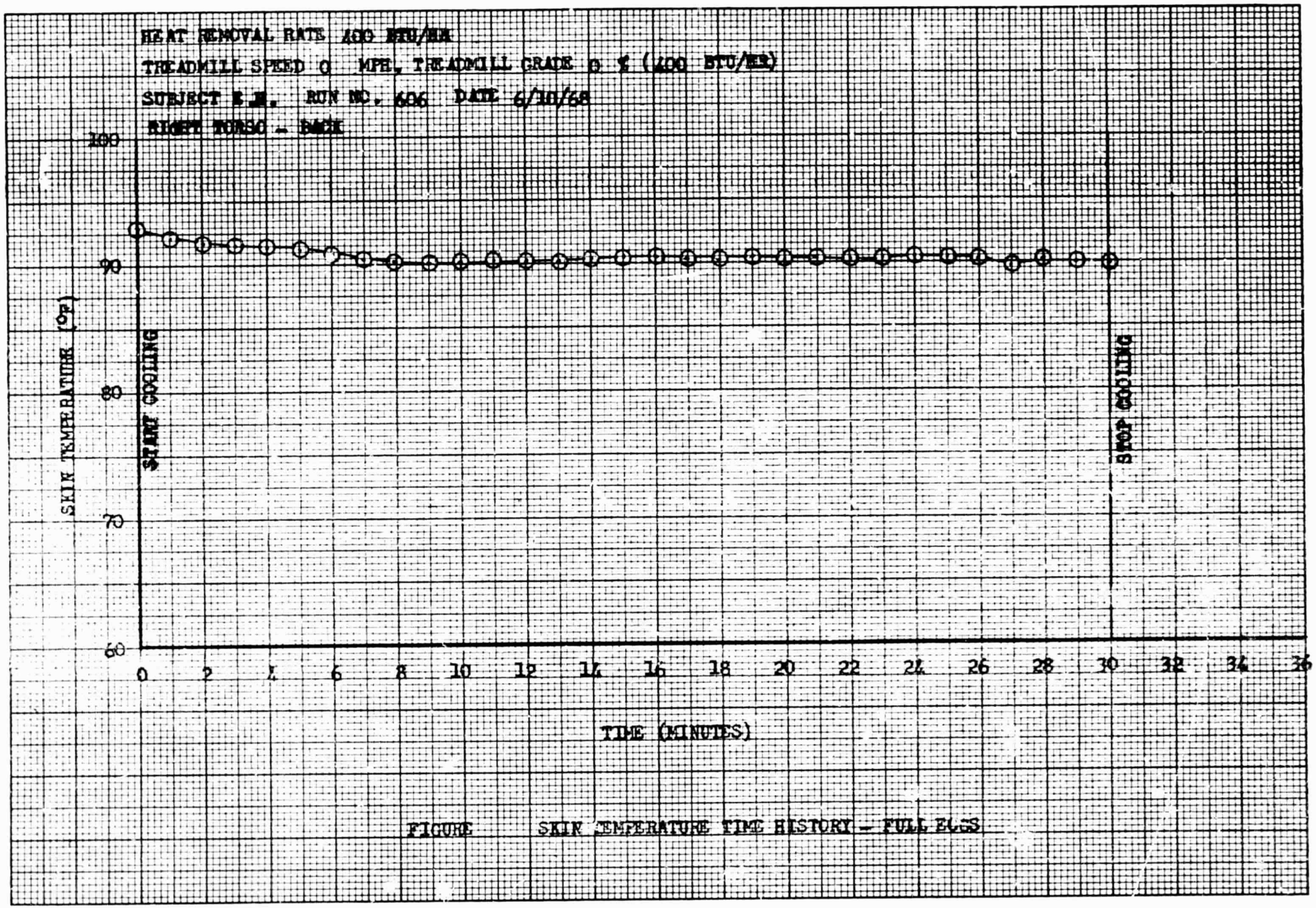


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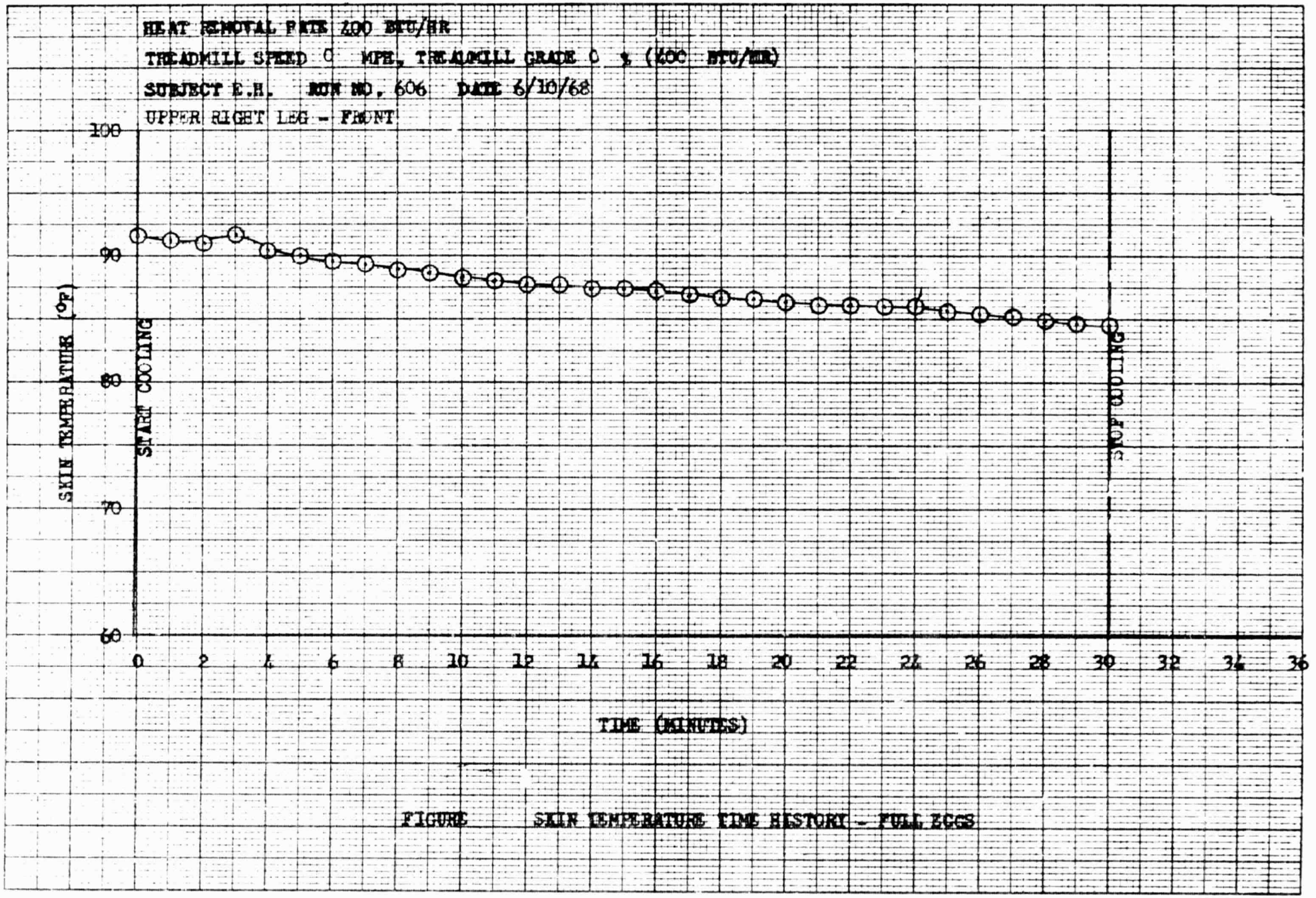


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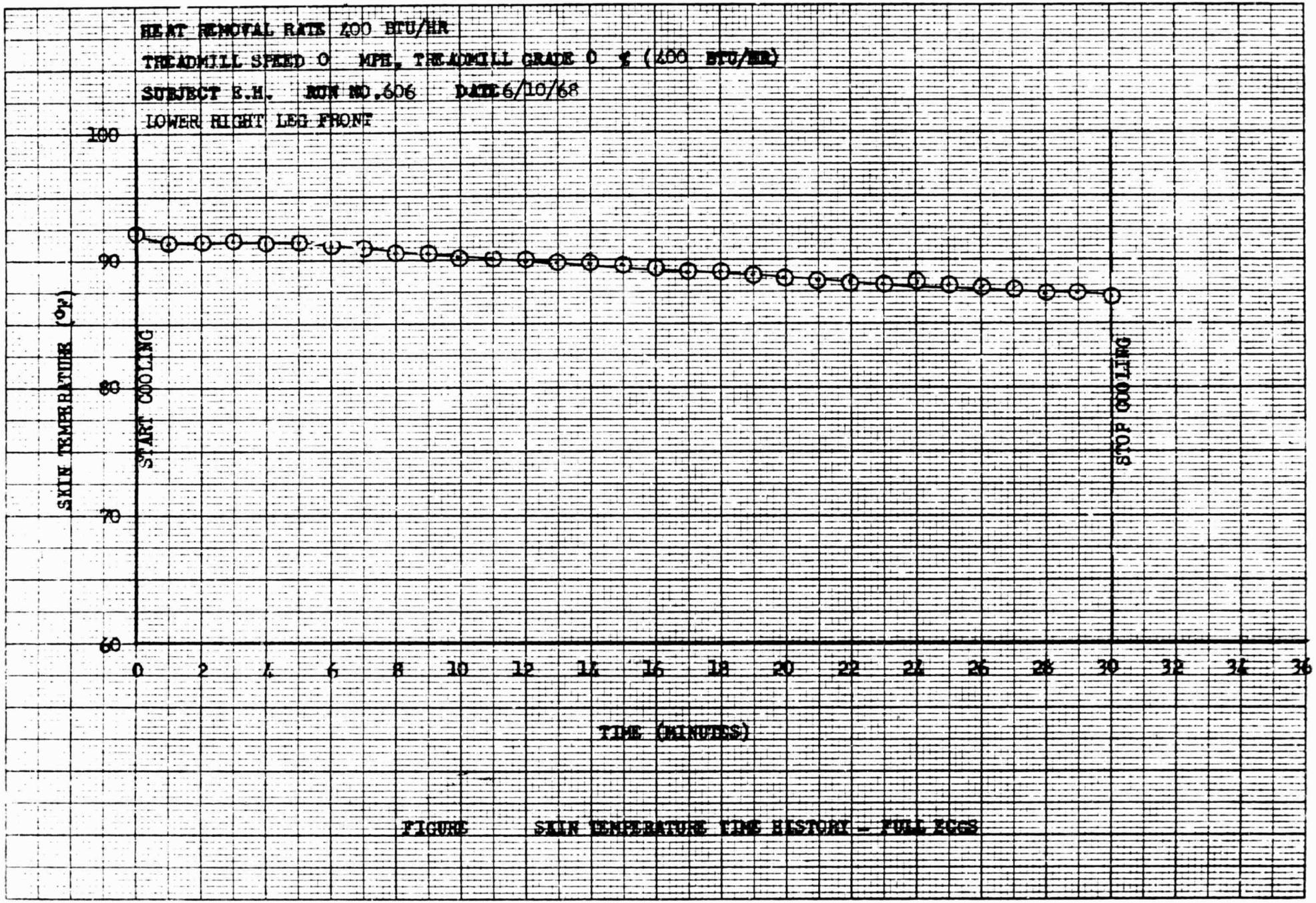


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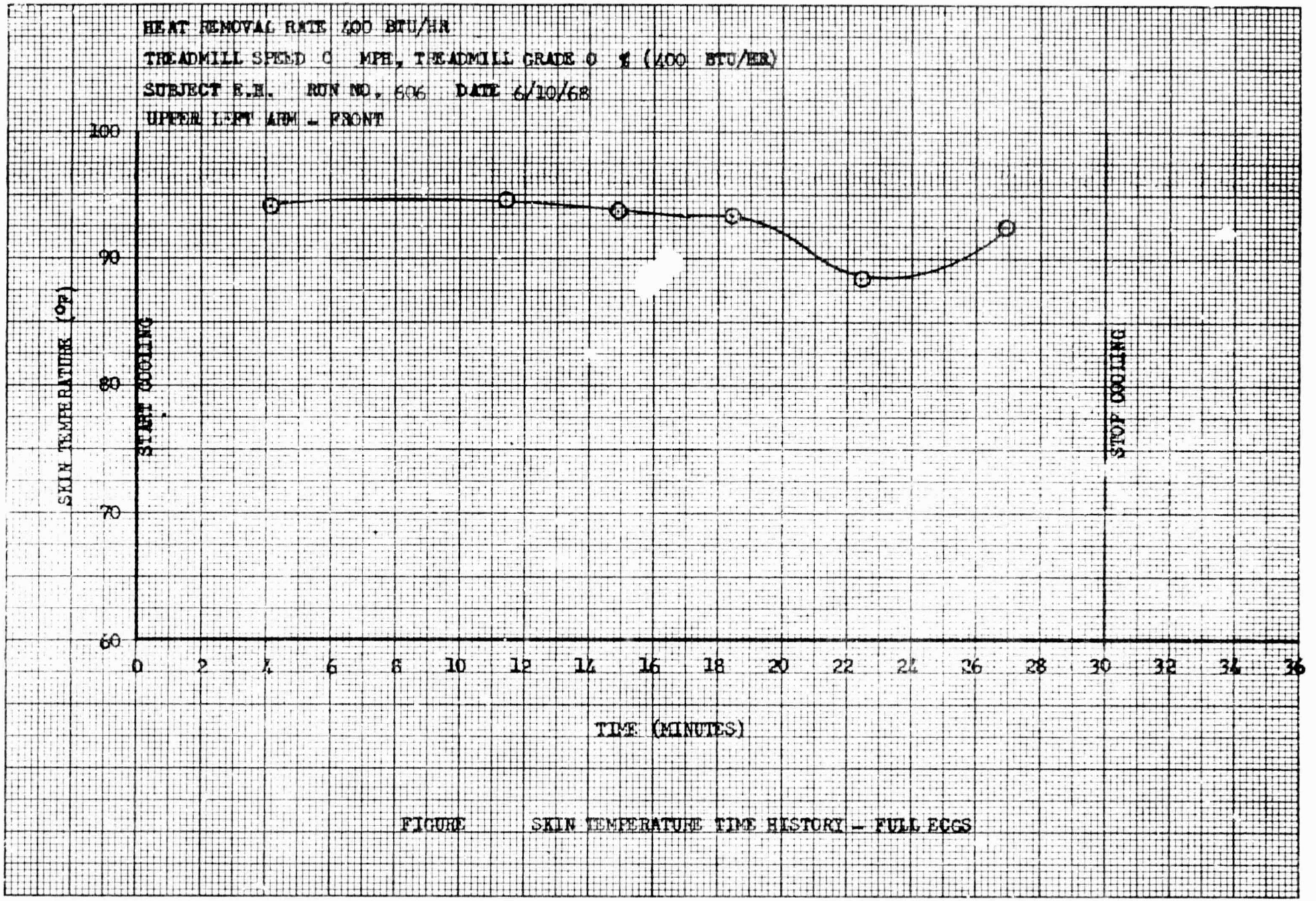


FIGURE SKIN TEMPERATURE TIME HISTORY – FULL ECGS

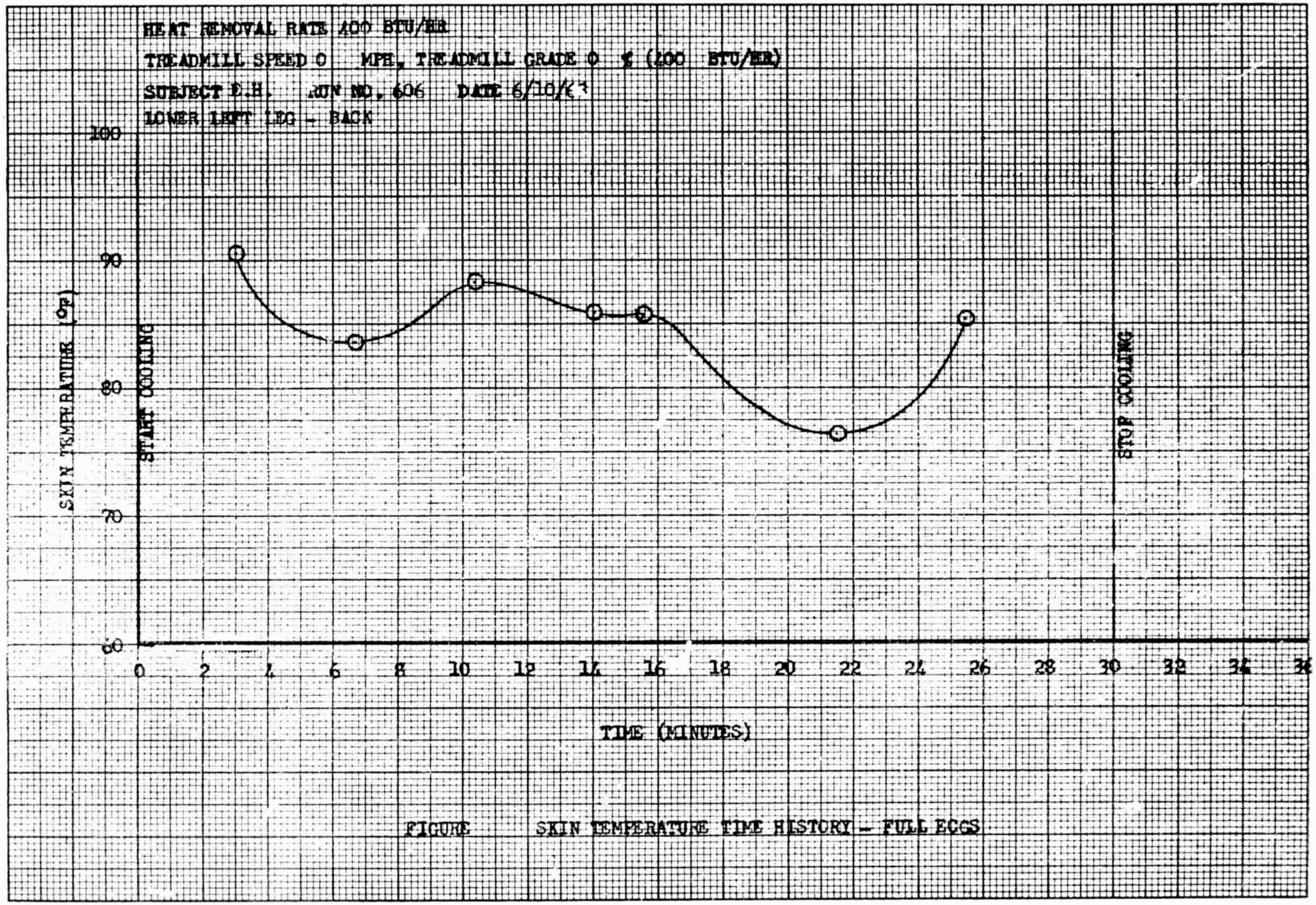


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

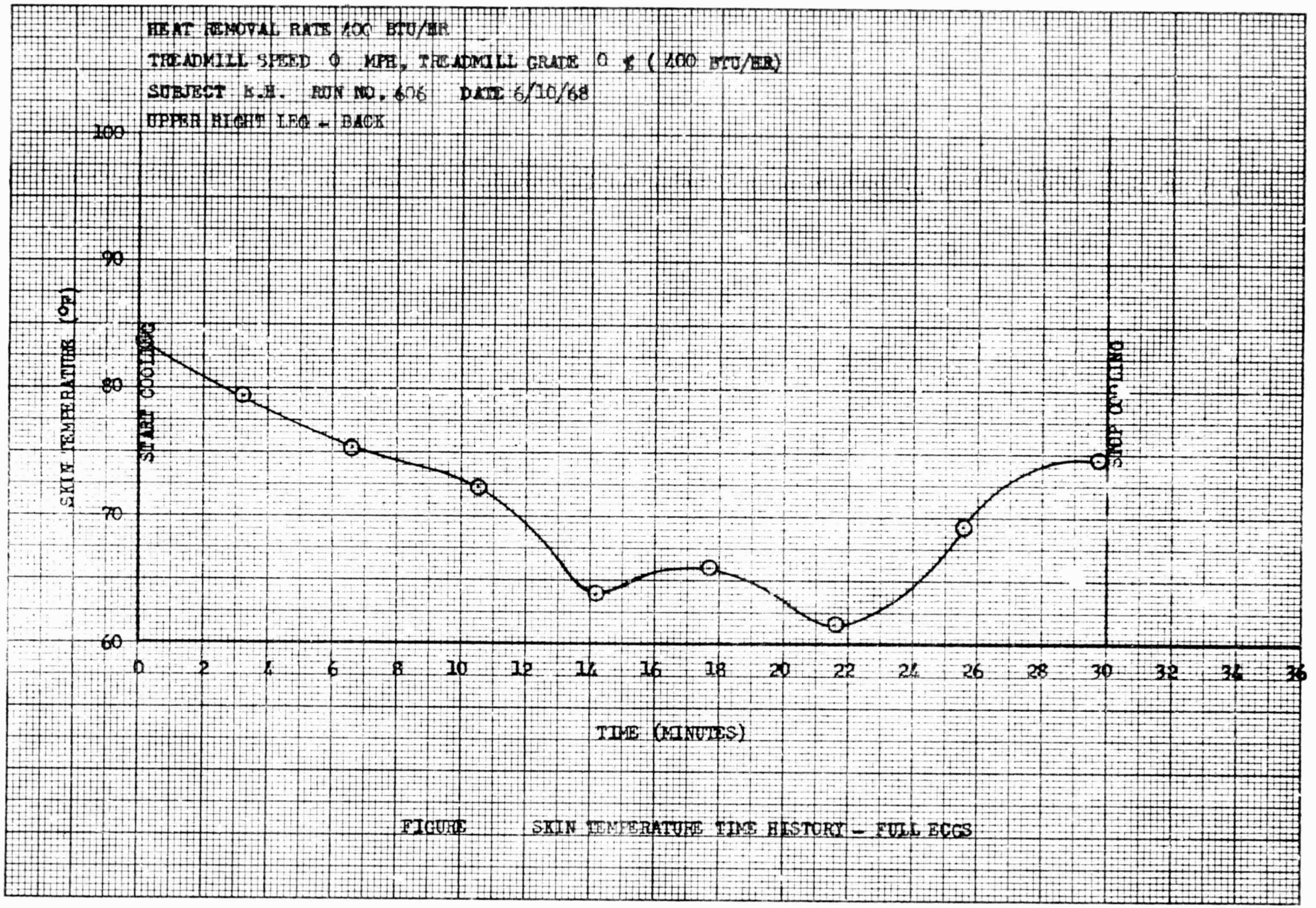


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

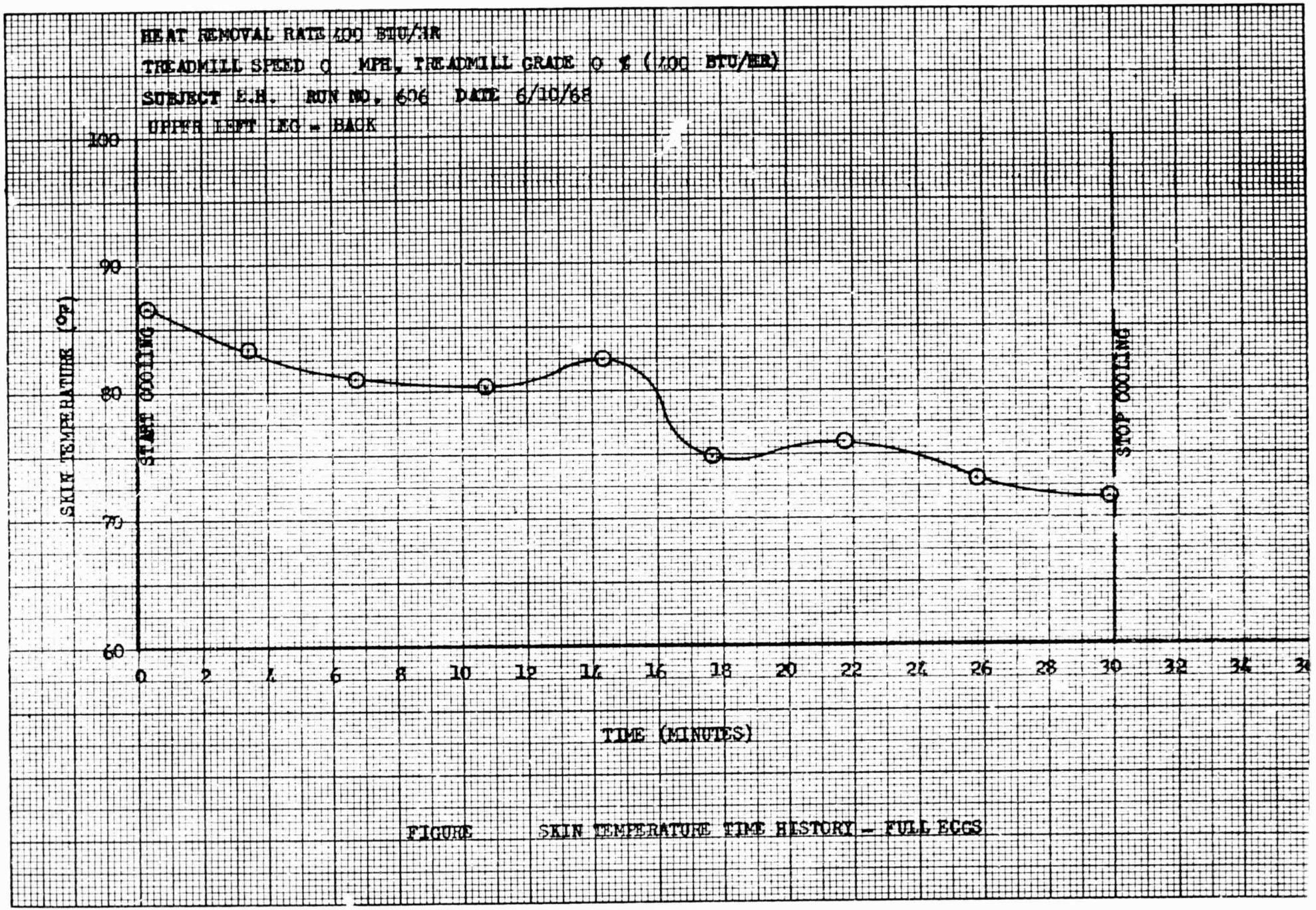


FIGURE SKIN TEMPERATURE TIME HISTORY – FULL ECGS

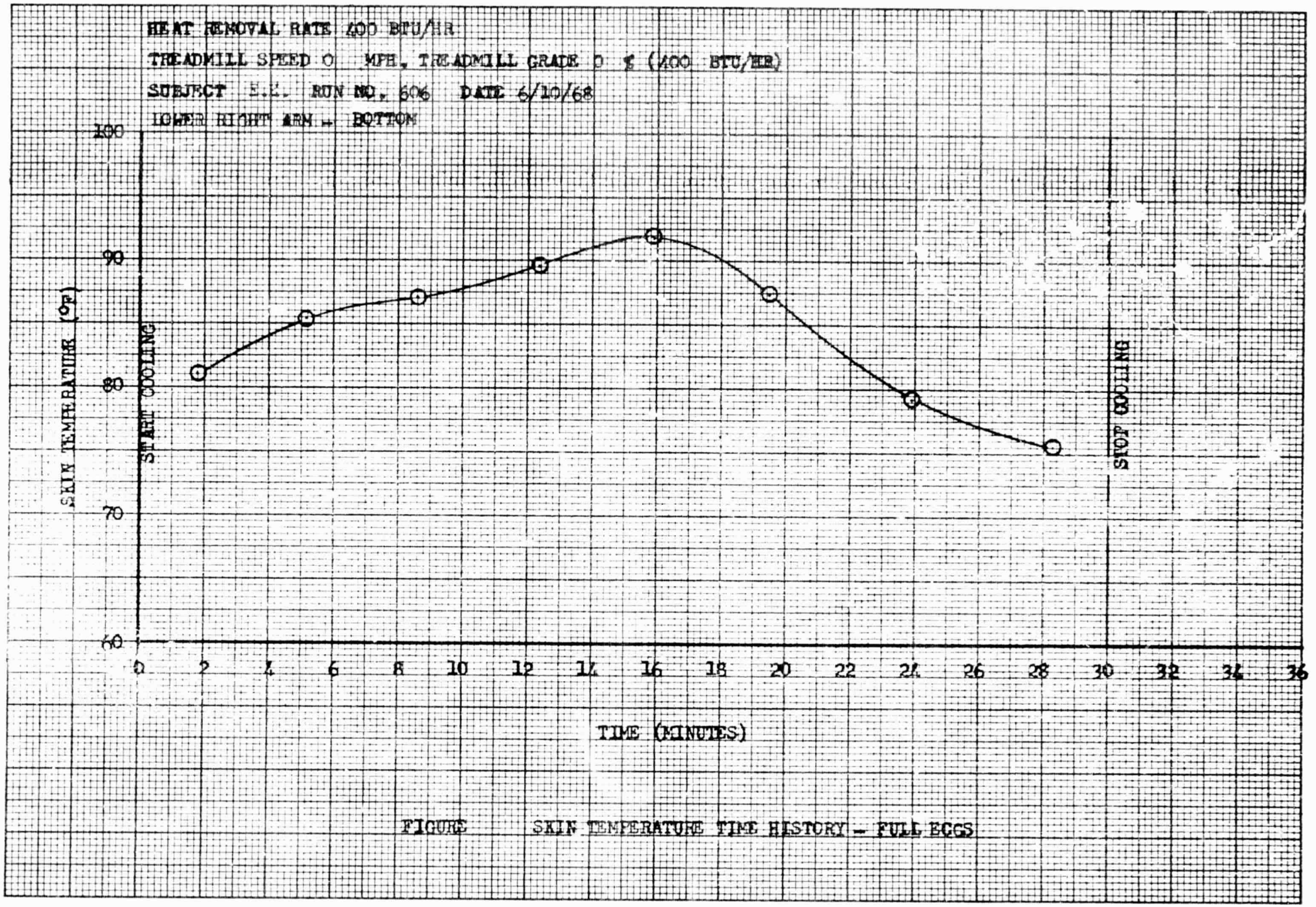


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

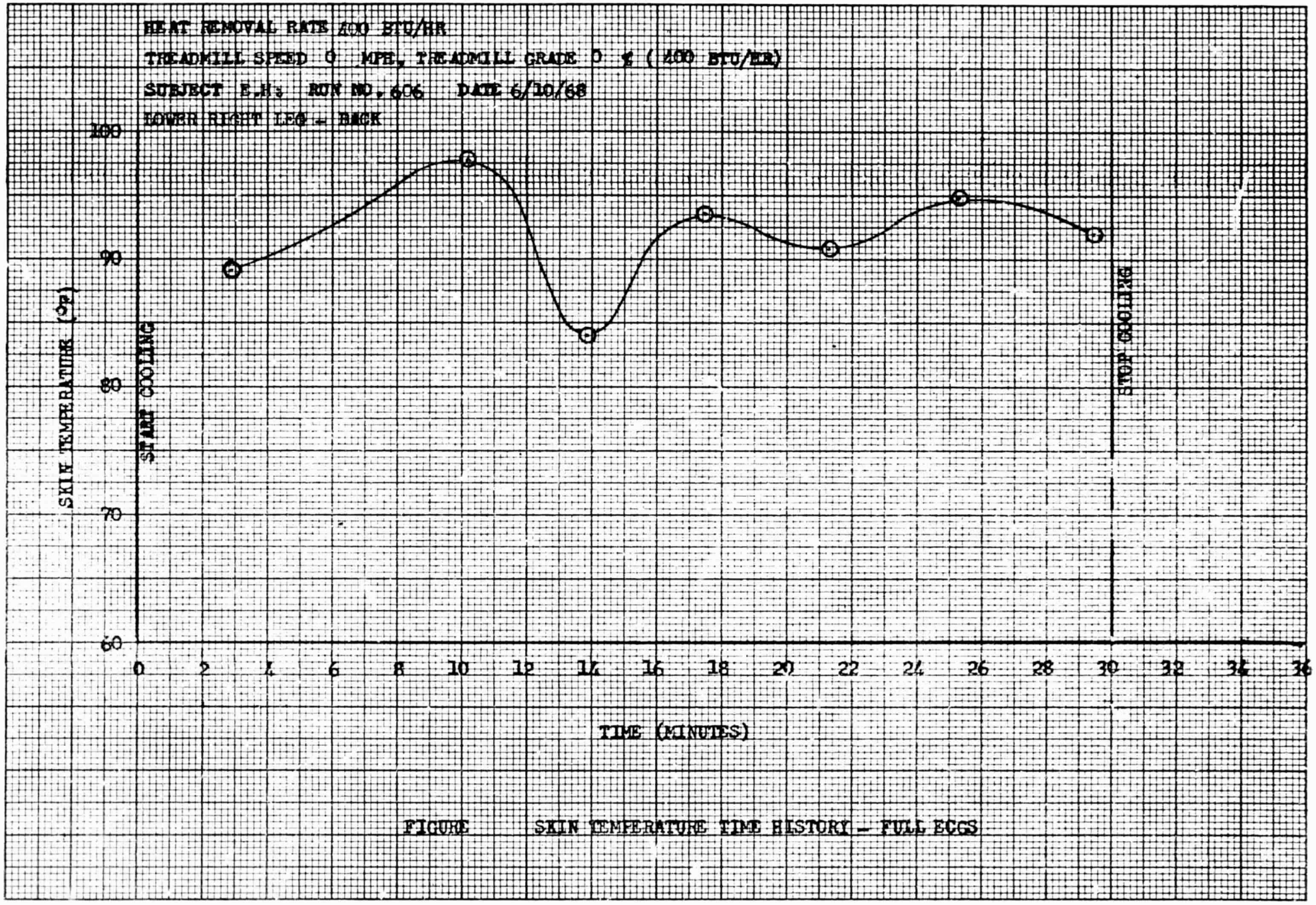


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

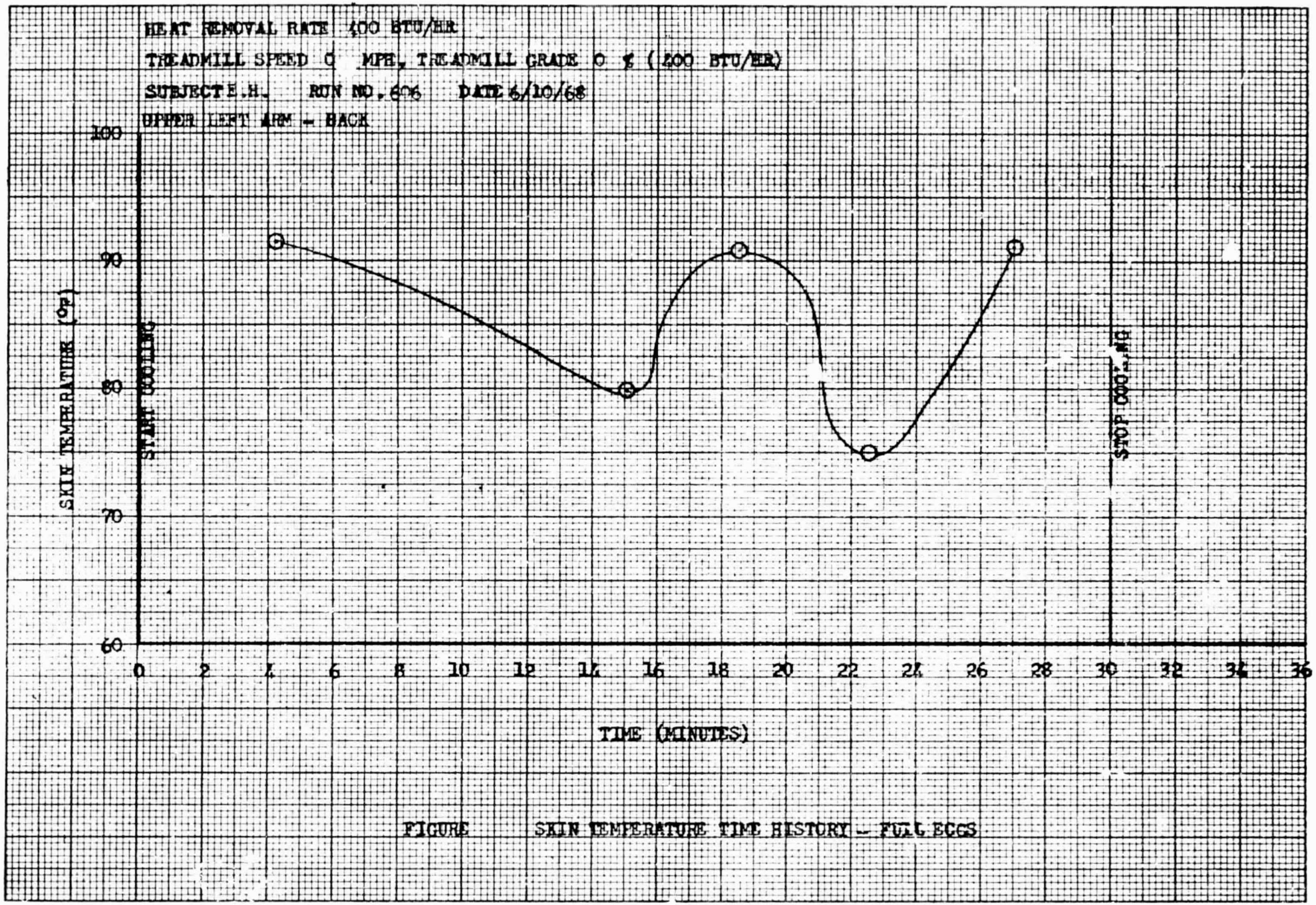


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

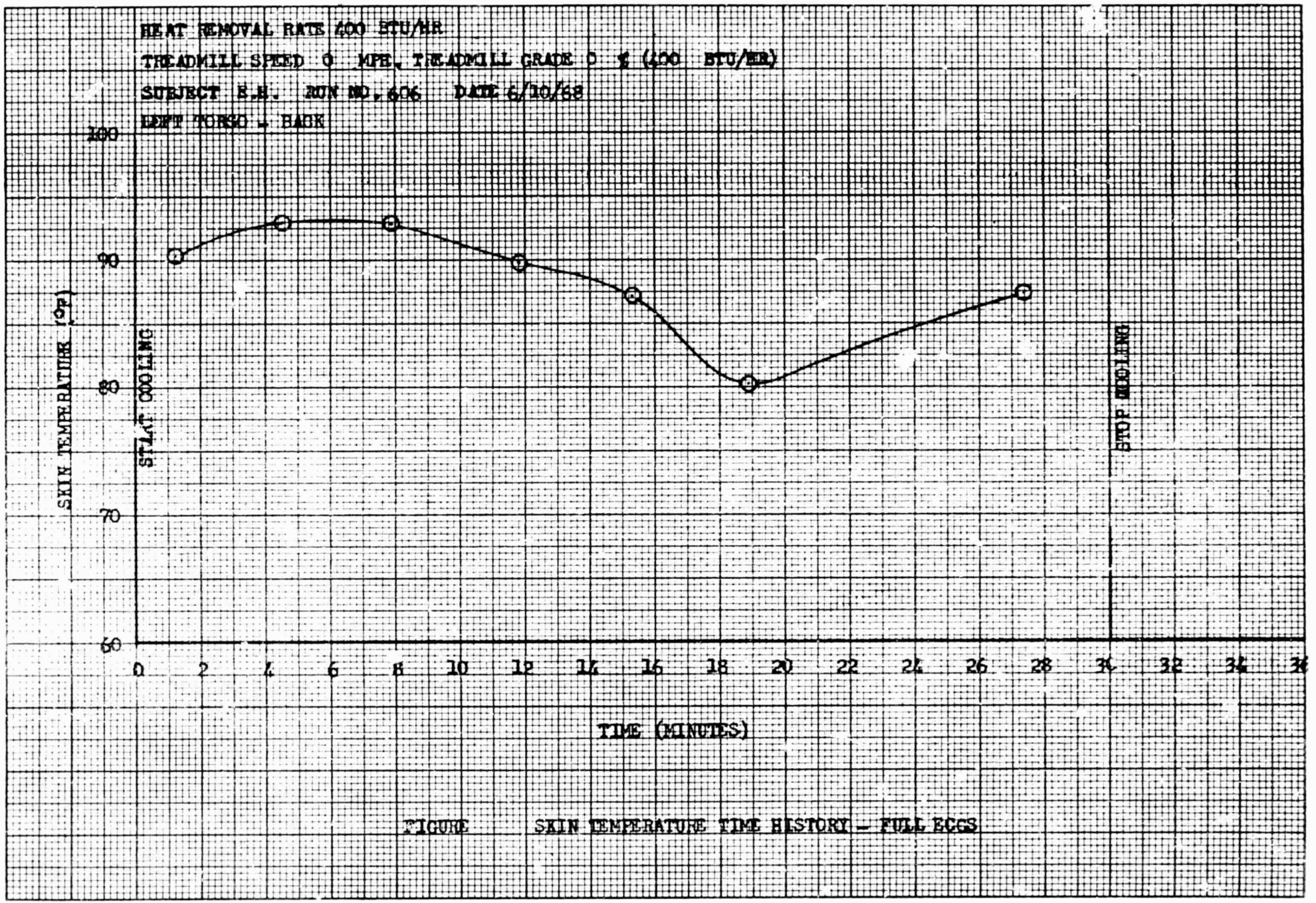


FIGURE SKIN TEMPERATURE TIME HISTORY – FULL ECGS

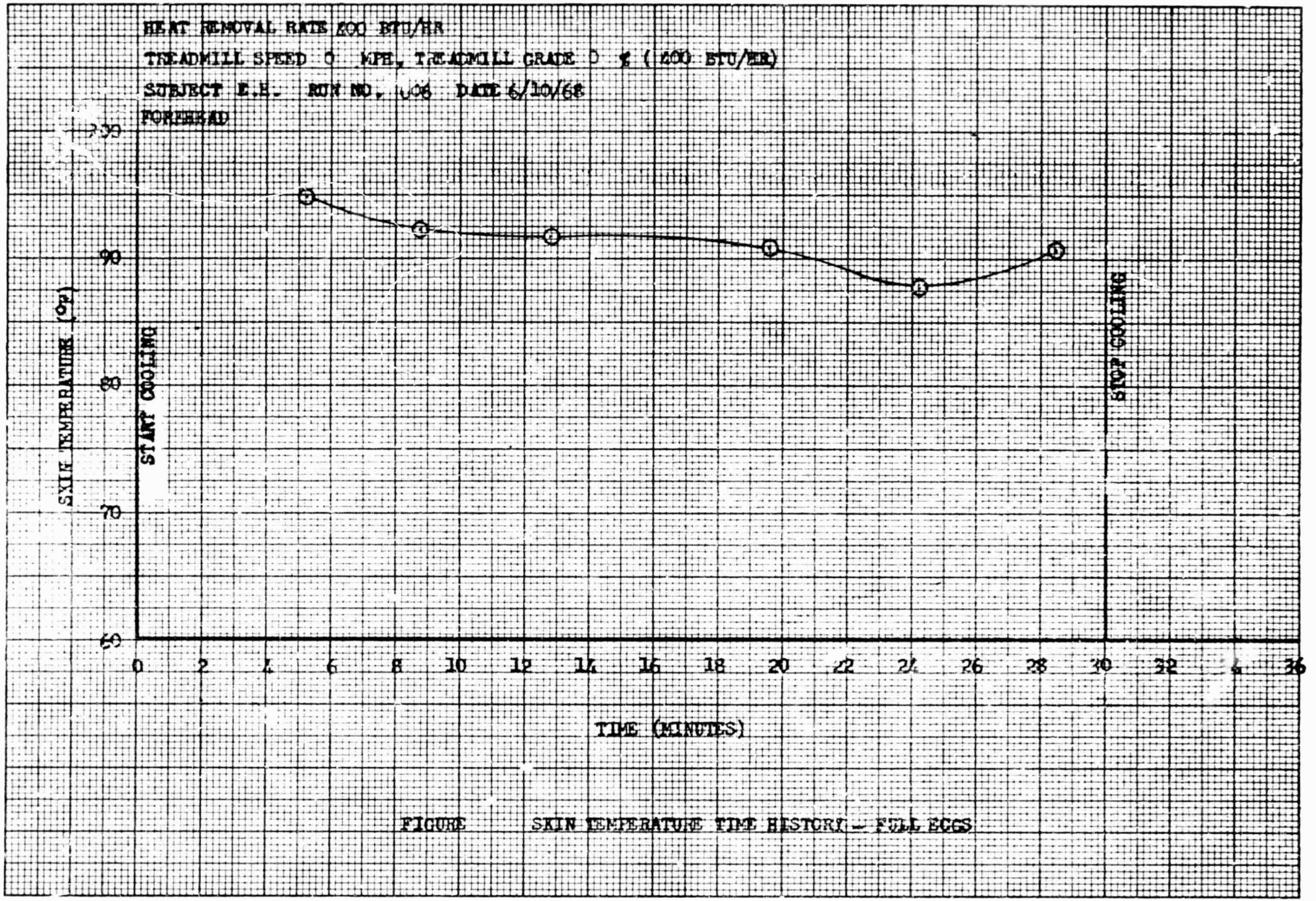


FIGURE SKIN TEMPERATURE TIME HISTORY – FULL ECGS

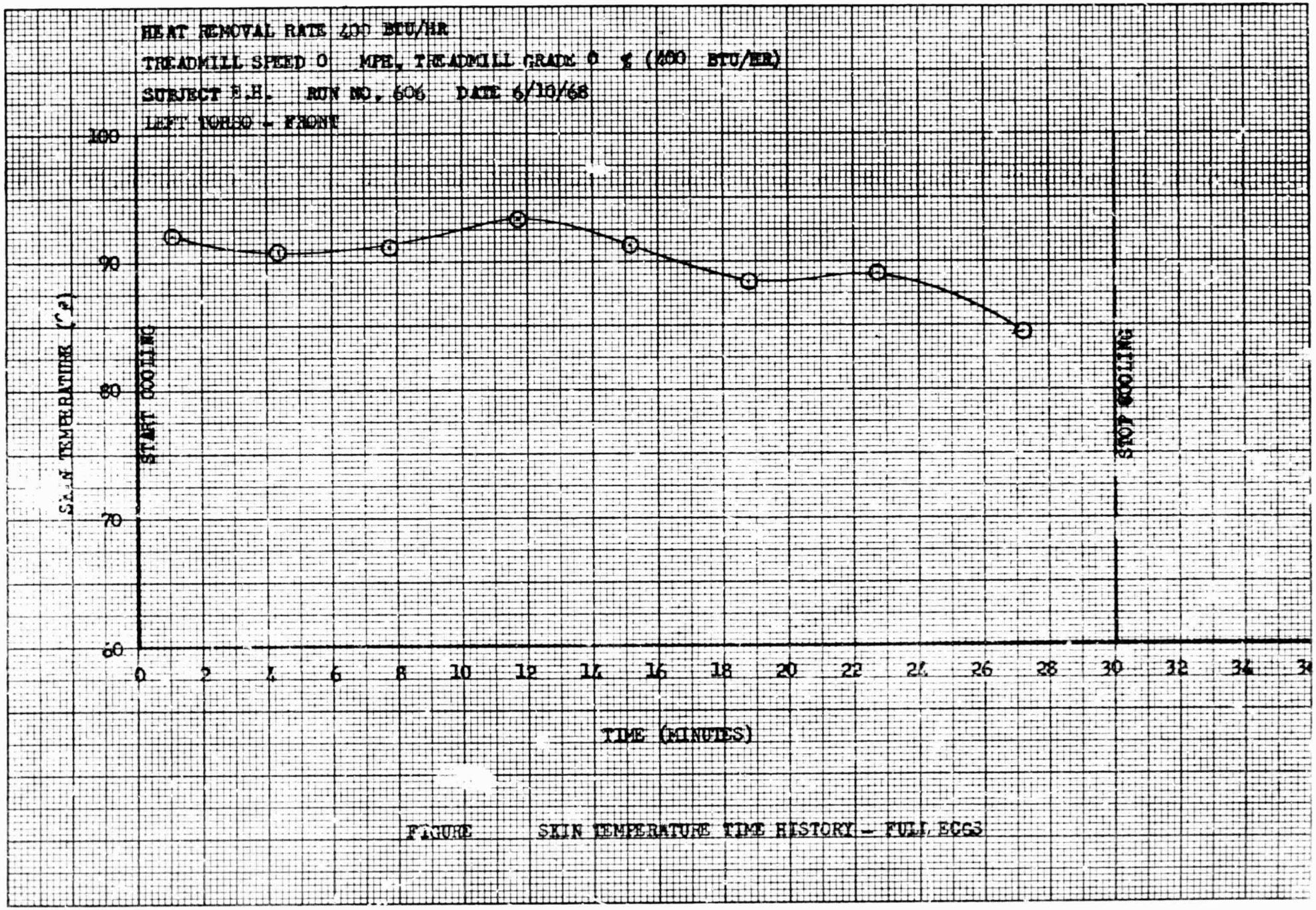


FIGURE SKIN TEMPERATURE TIME HISTORY - FULL ECGS

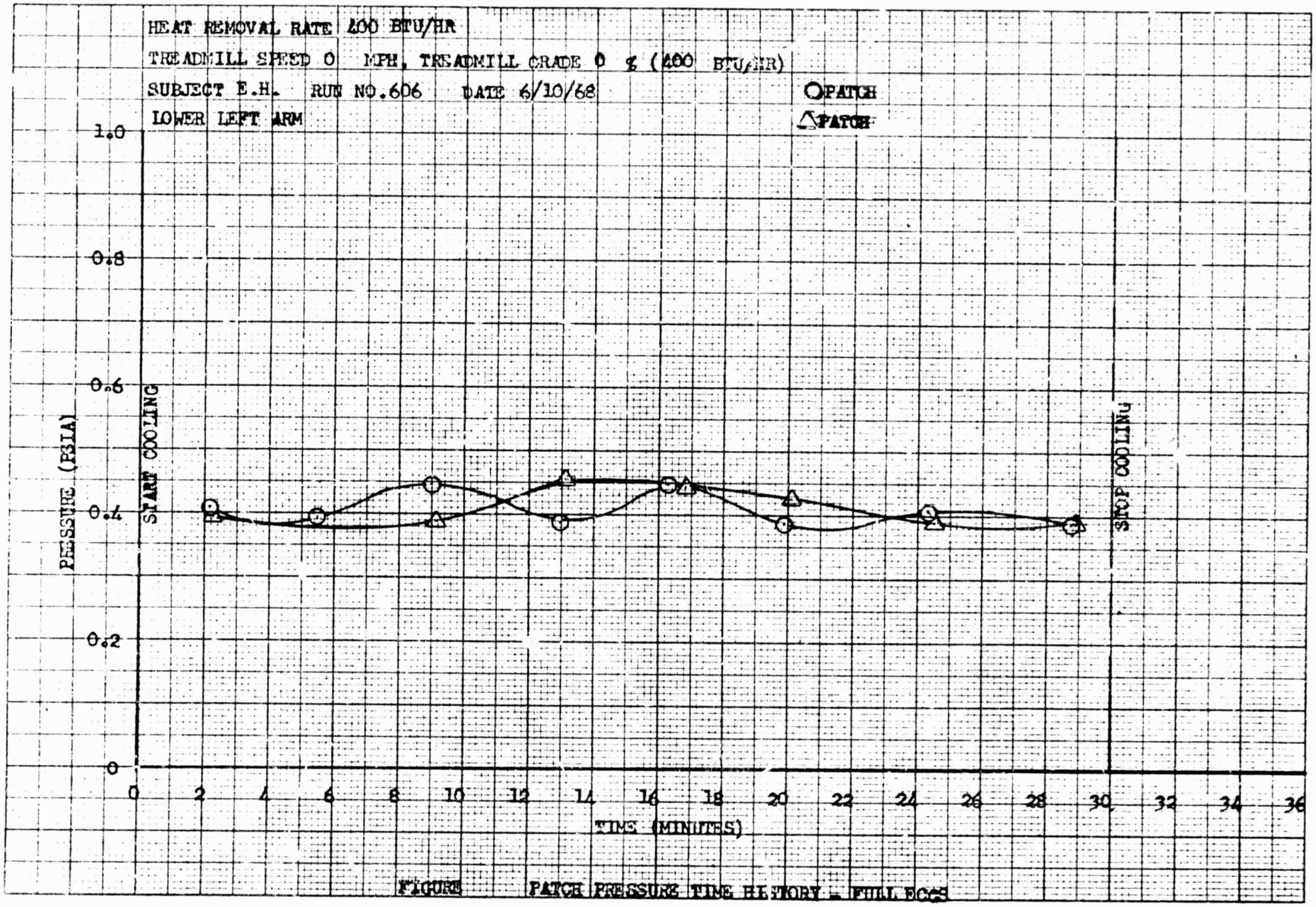


FIGURE PATCH PRESSURE TIME HISTORY - FULL ECCS

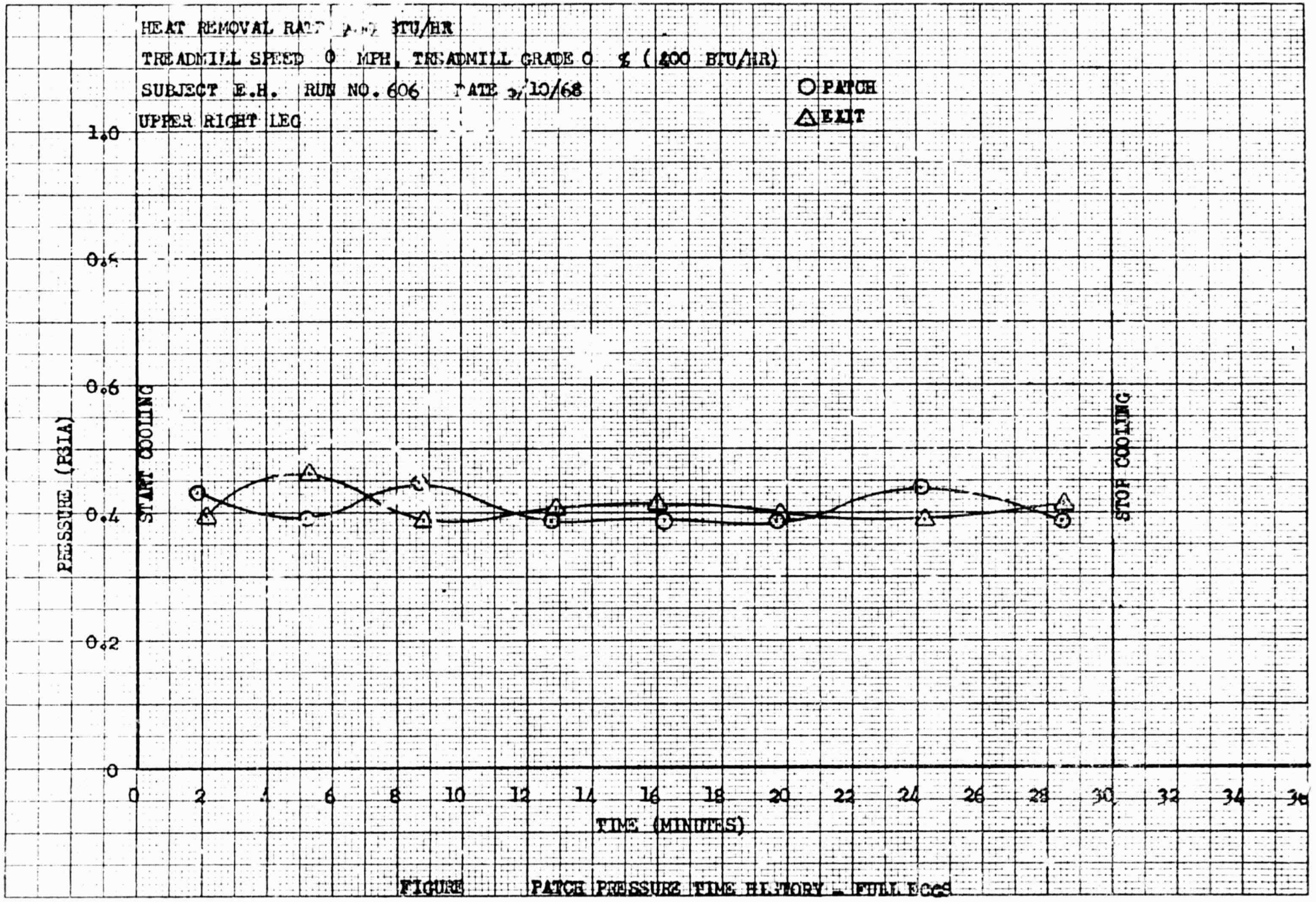


FIGURE PATCH PRESSURE TIME HISTORY - FULL LEGS

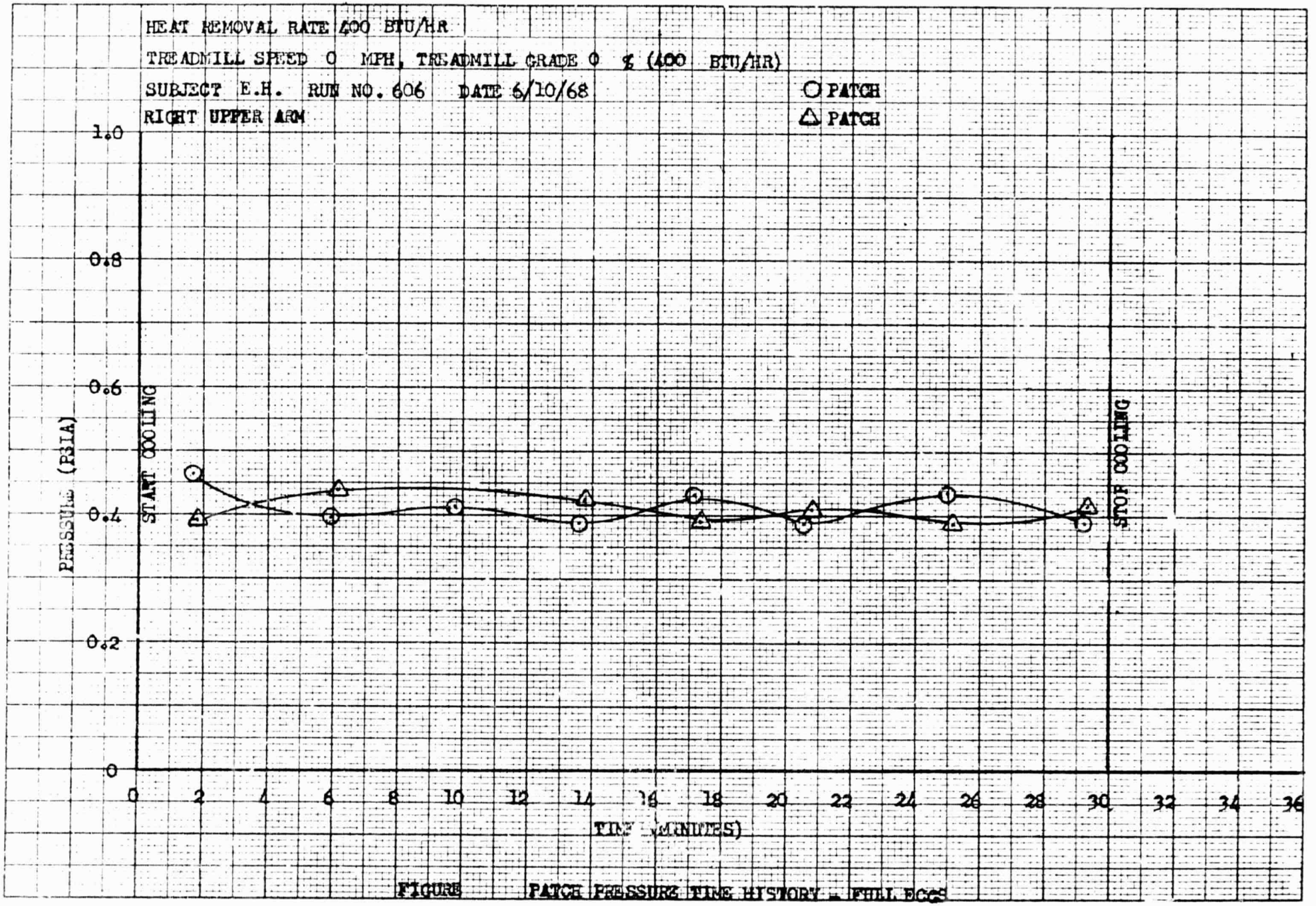


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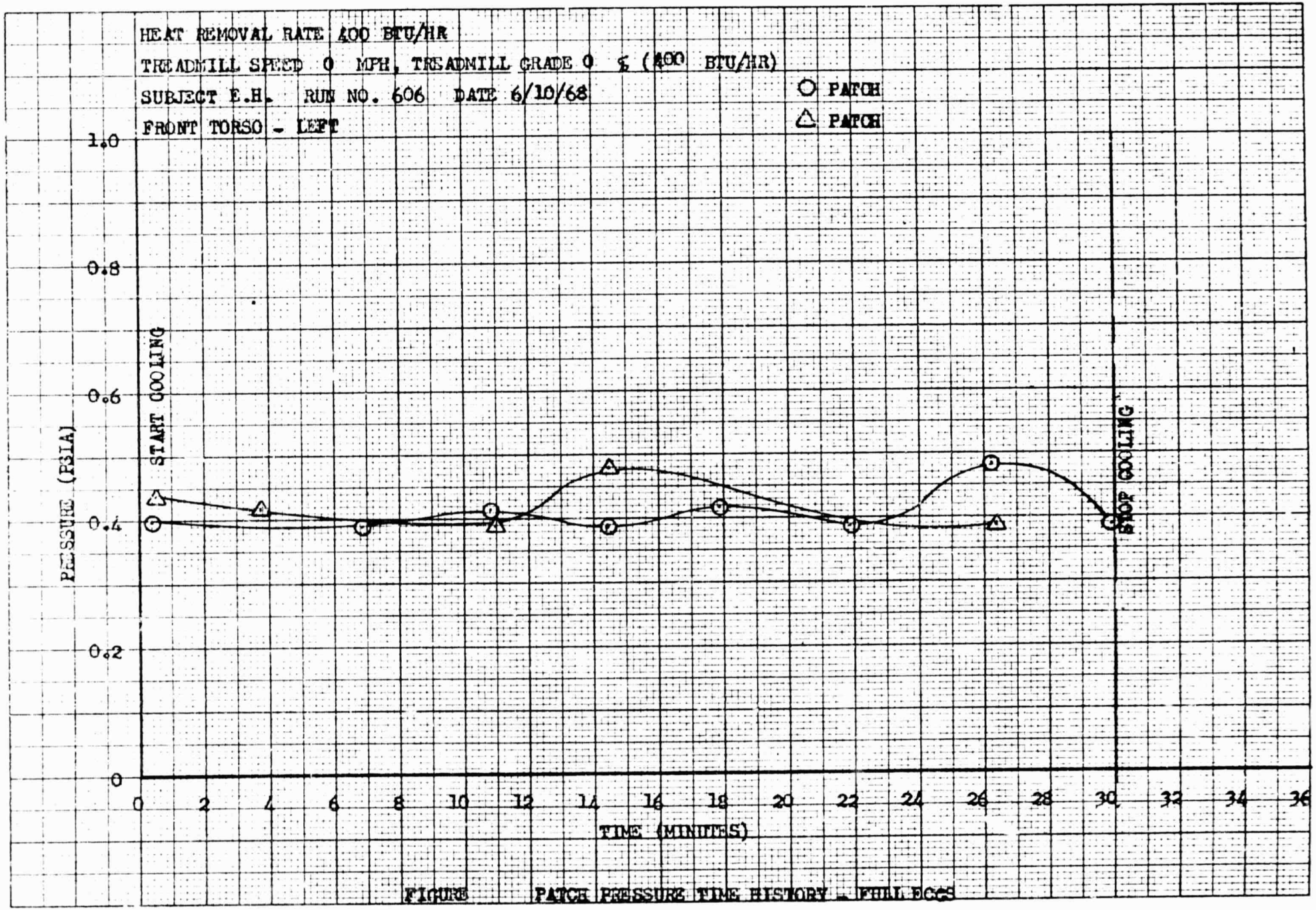


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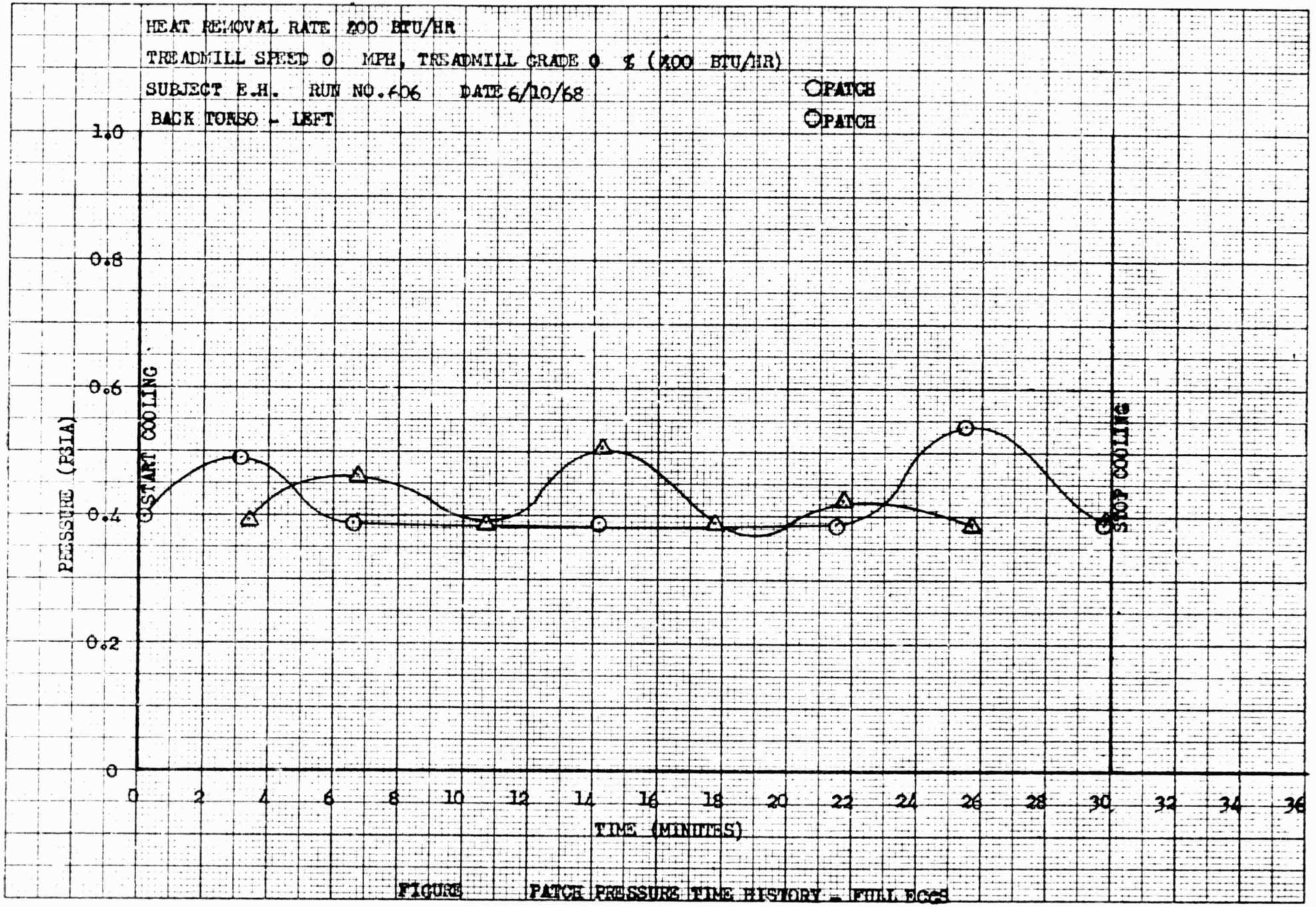


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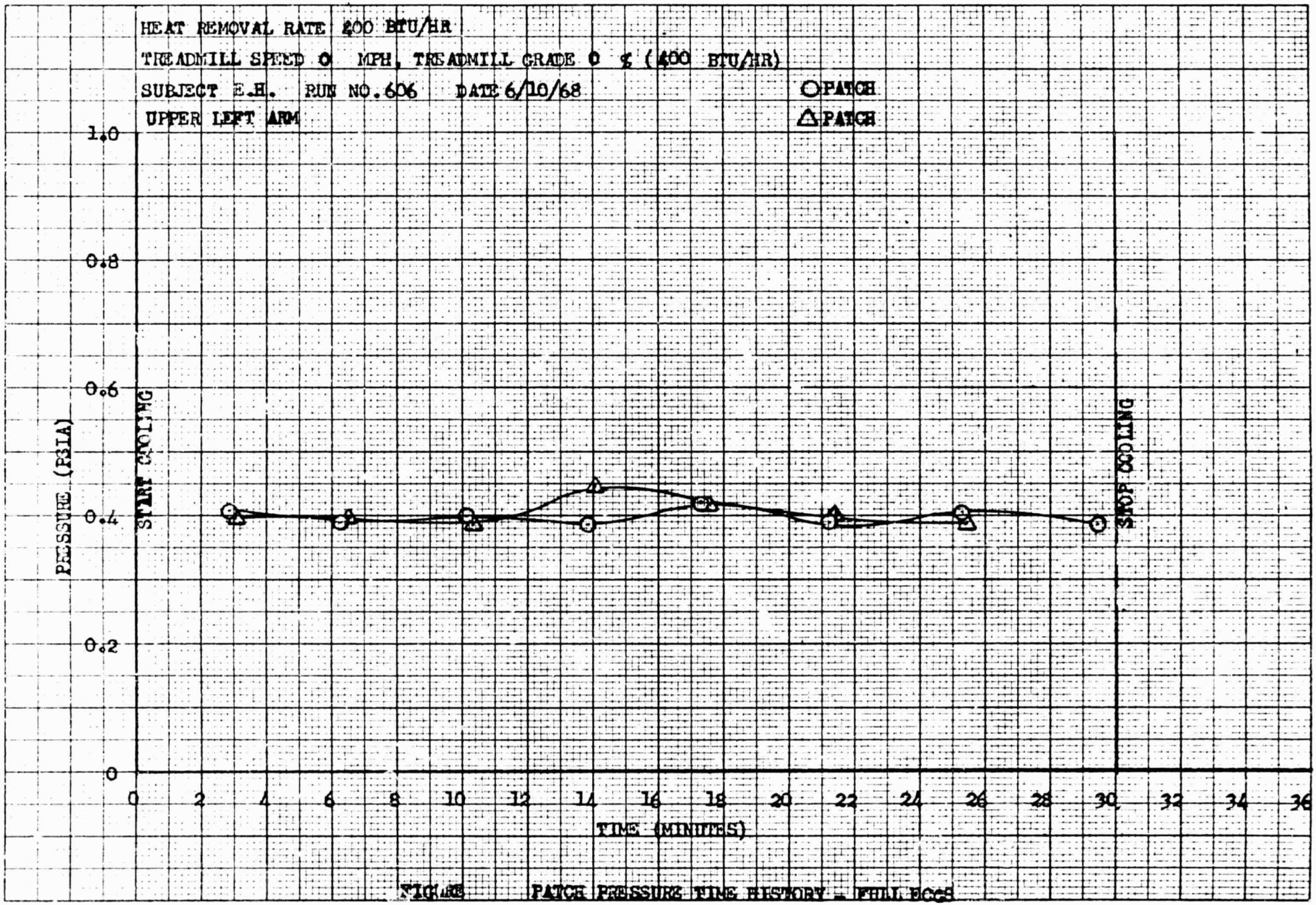


FIGURE PATCH PRESSURE TIME HISTORY - FULL ECCS

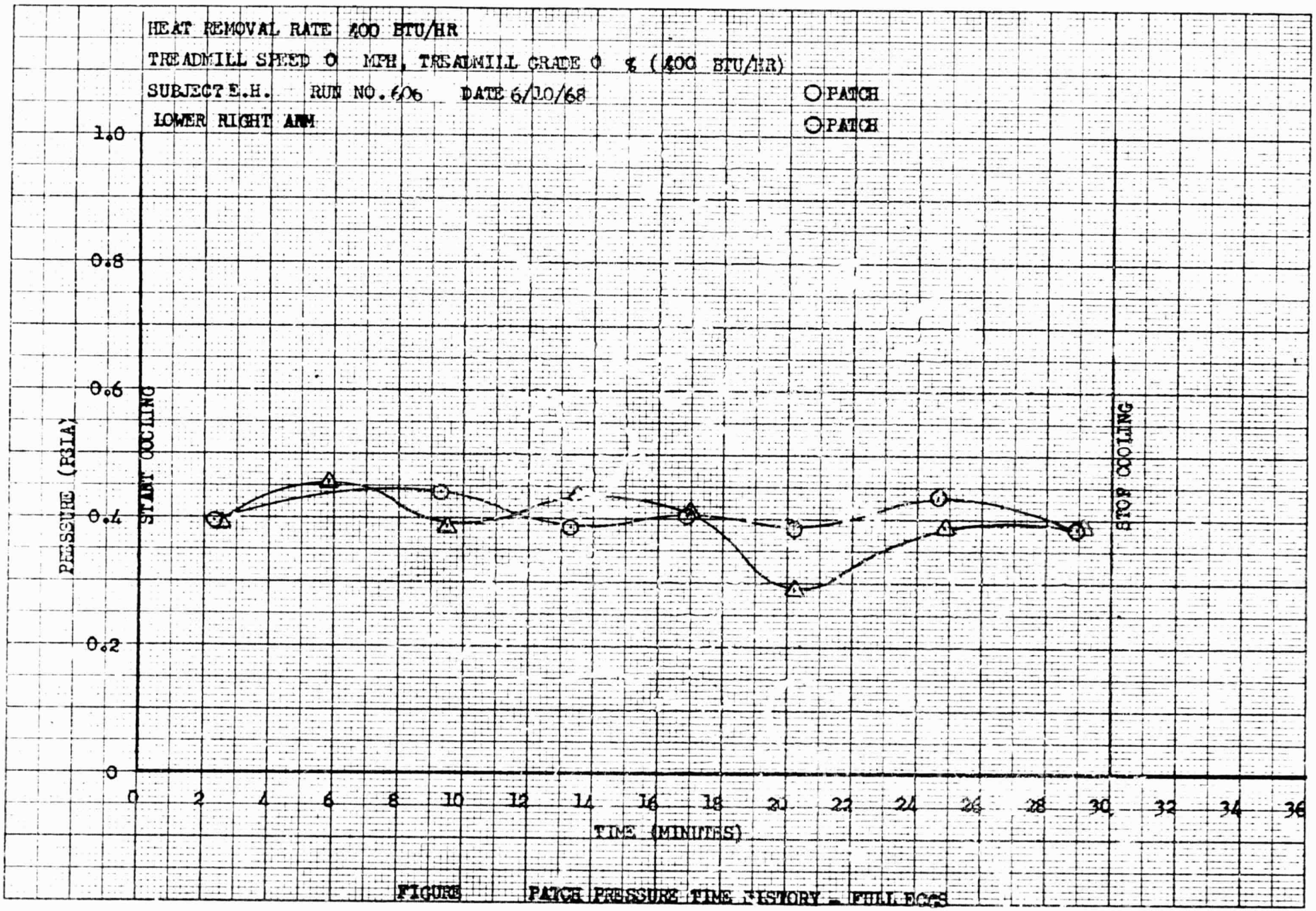


FIGURE PATCH PRESSURE TIME HISTORY - FULL ECCS

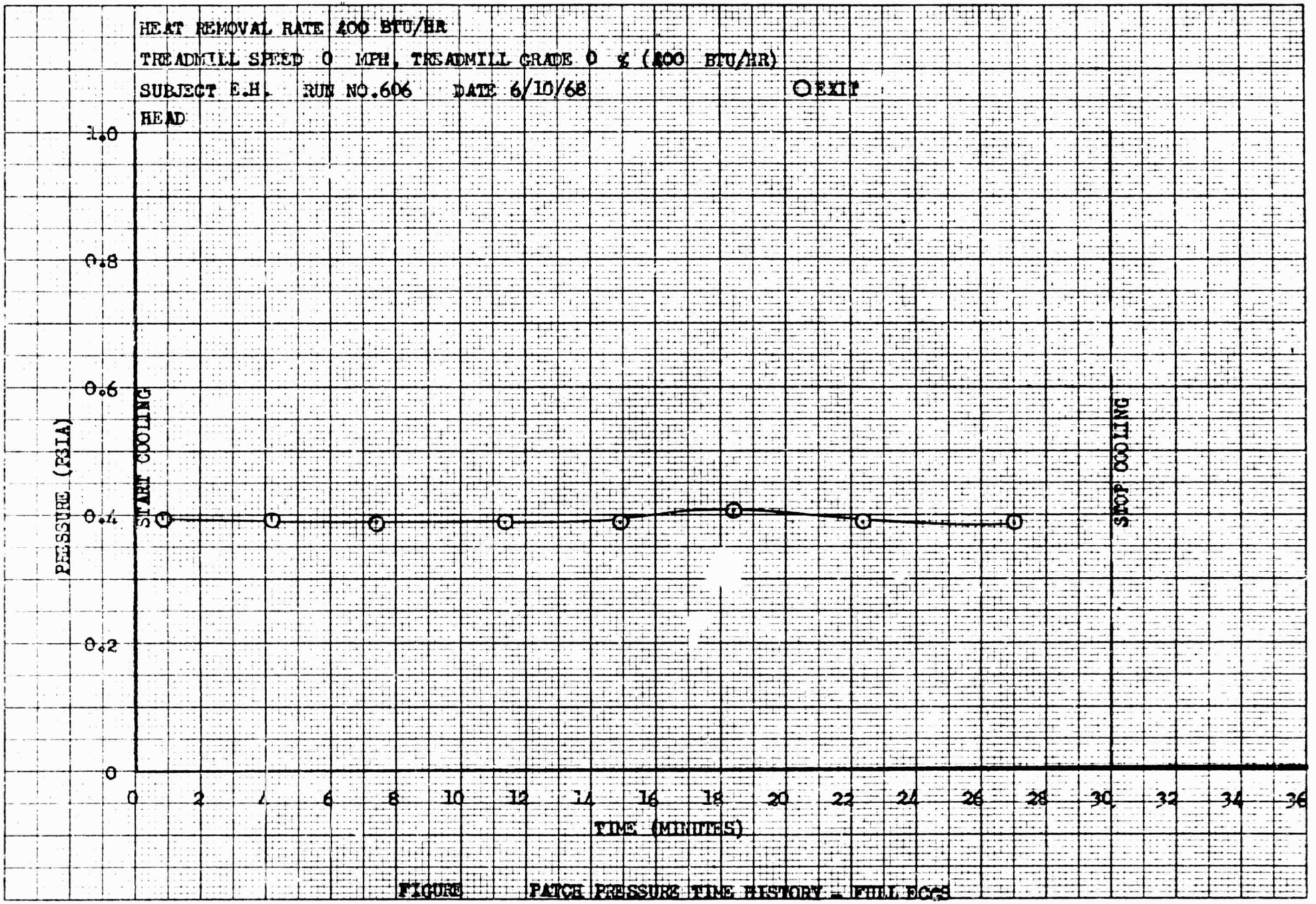


FIGURE PATCH PRESSURE TIME HISTORY - FULL ECGS

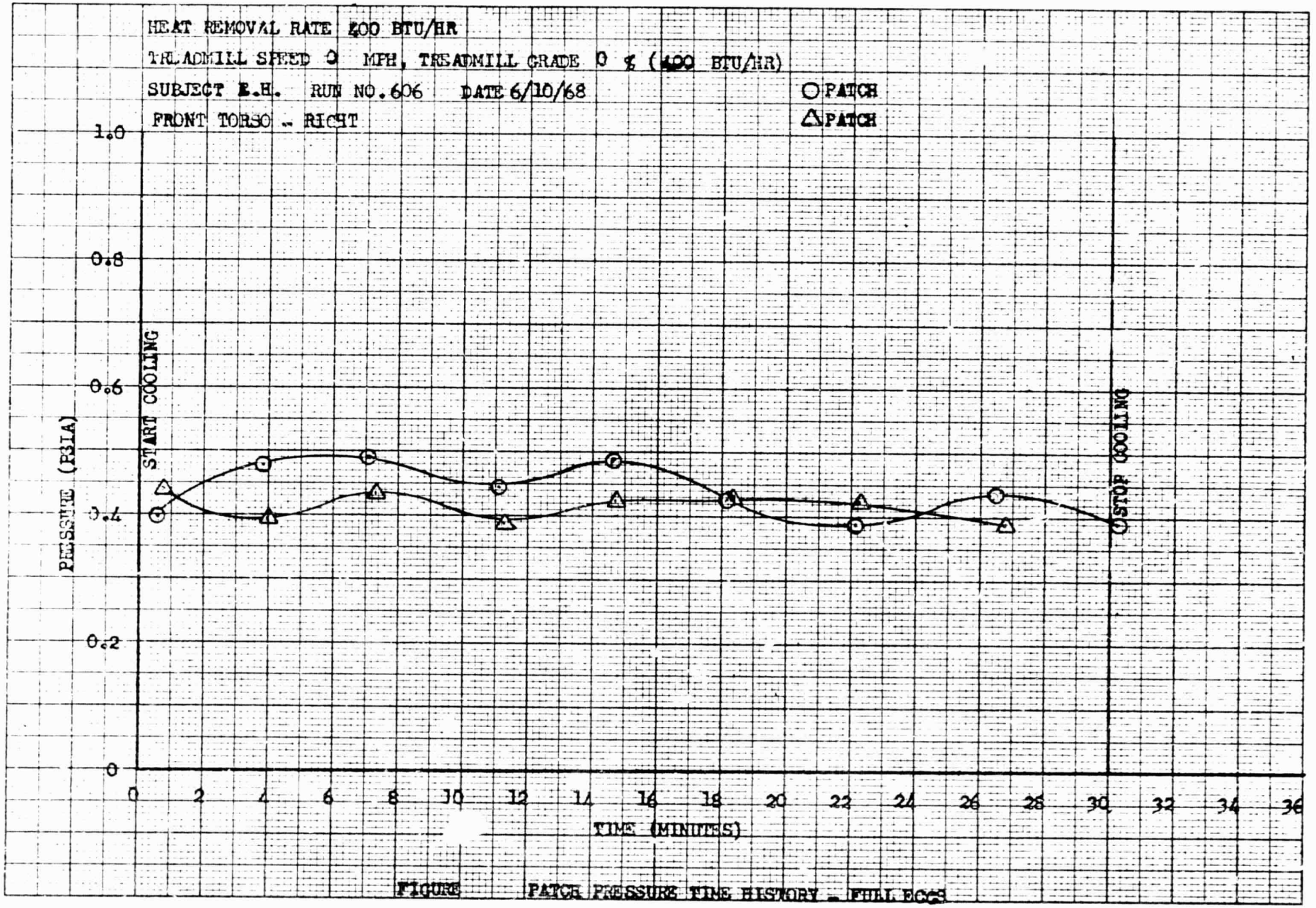


FIGURE PATCH PRESSURE TIME HISTORY - FULL ECCS

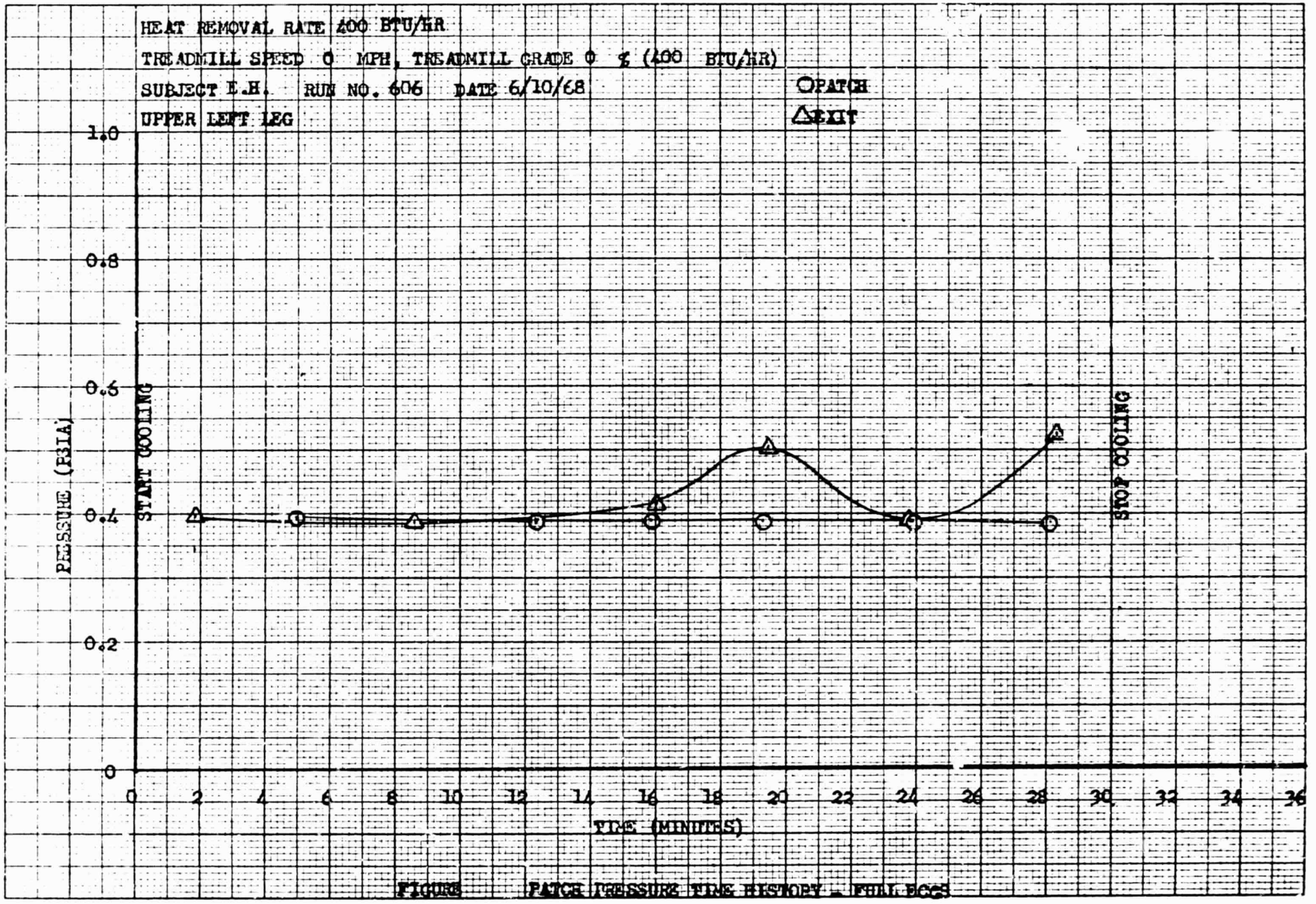


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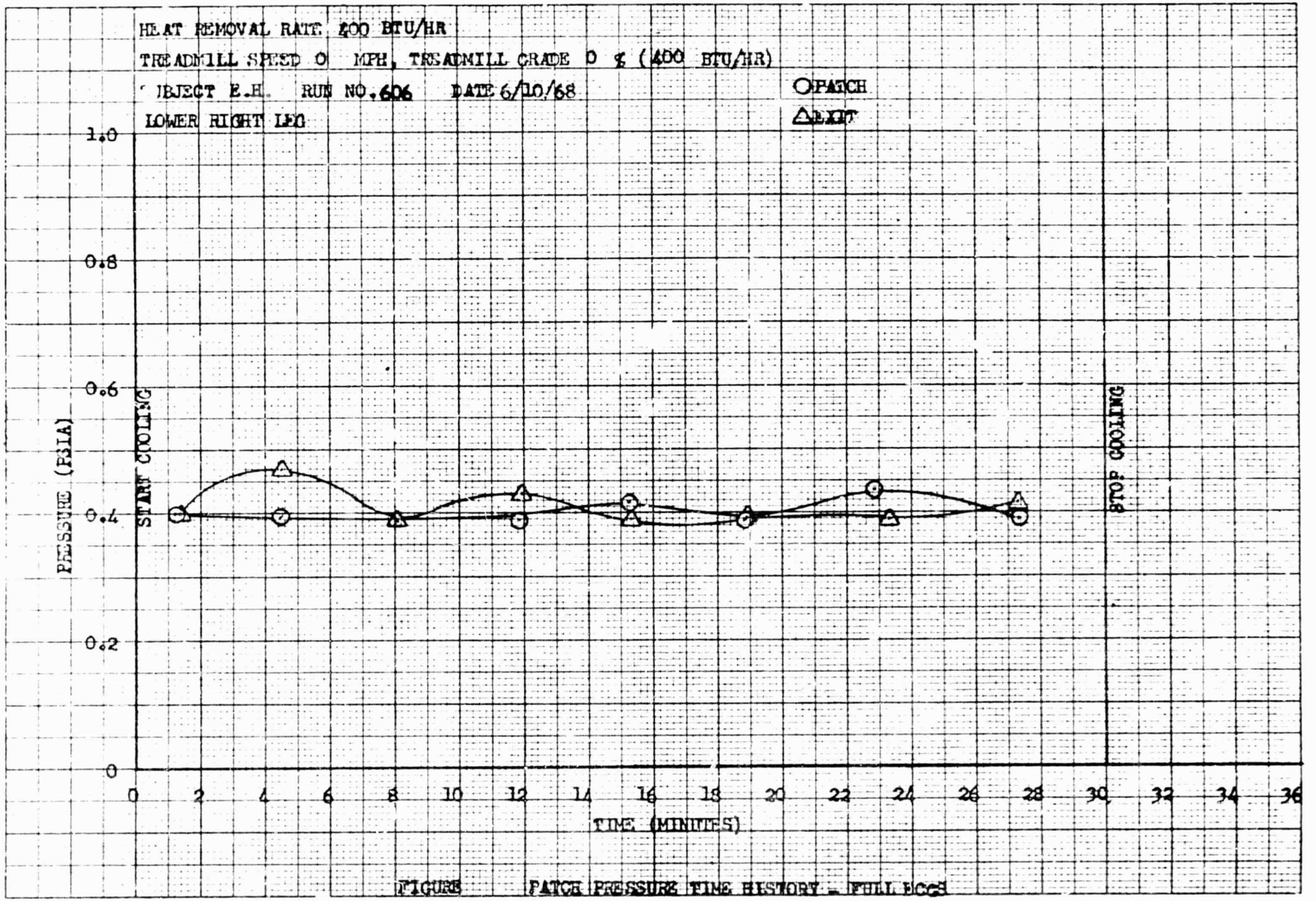


FIGURE PATCH PRESSURE TIME HISTORY - FULL ECG

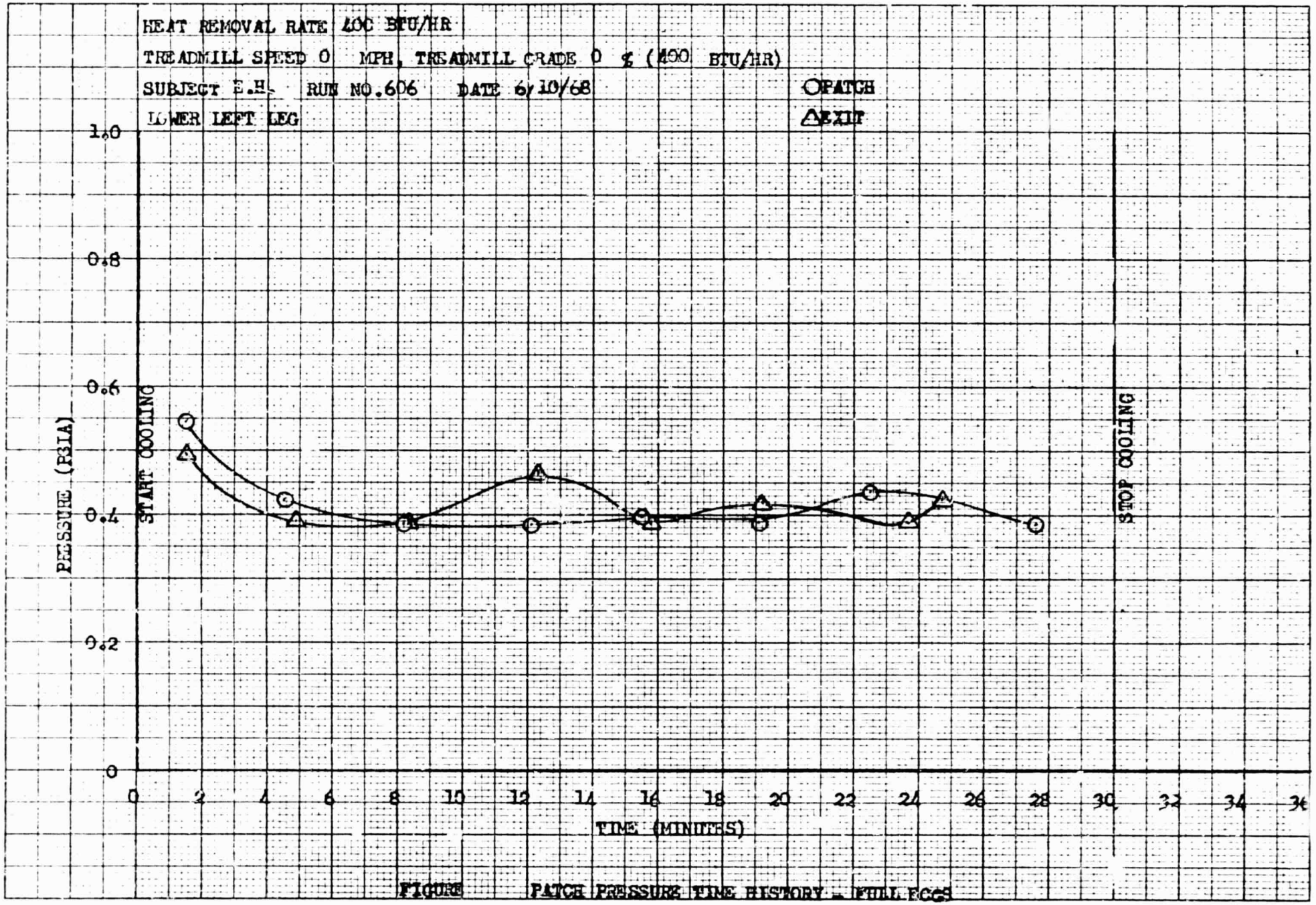
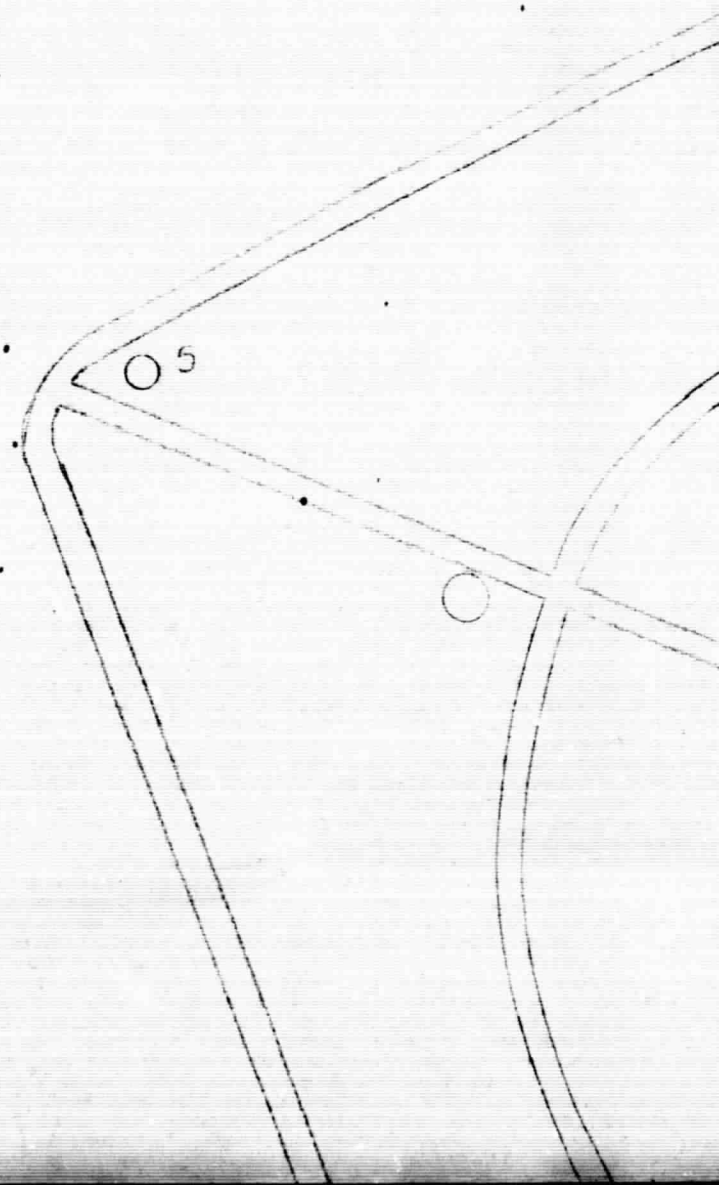


FIGURE PATCH PRESSURE TIME HISTORY - FULL EGGS

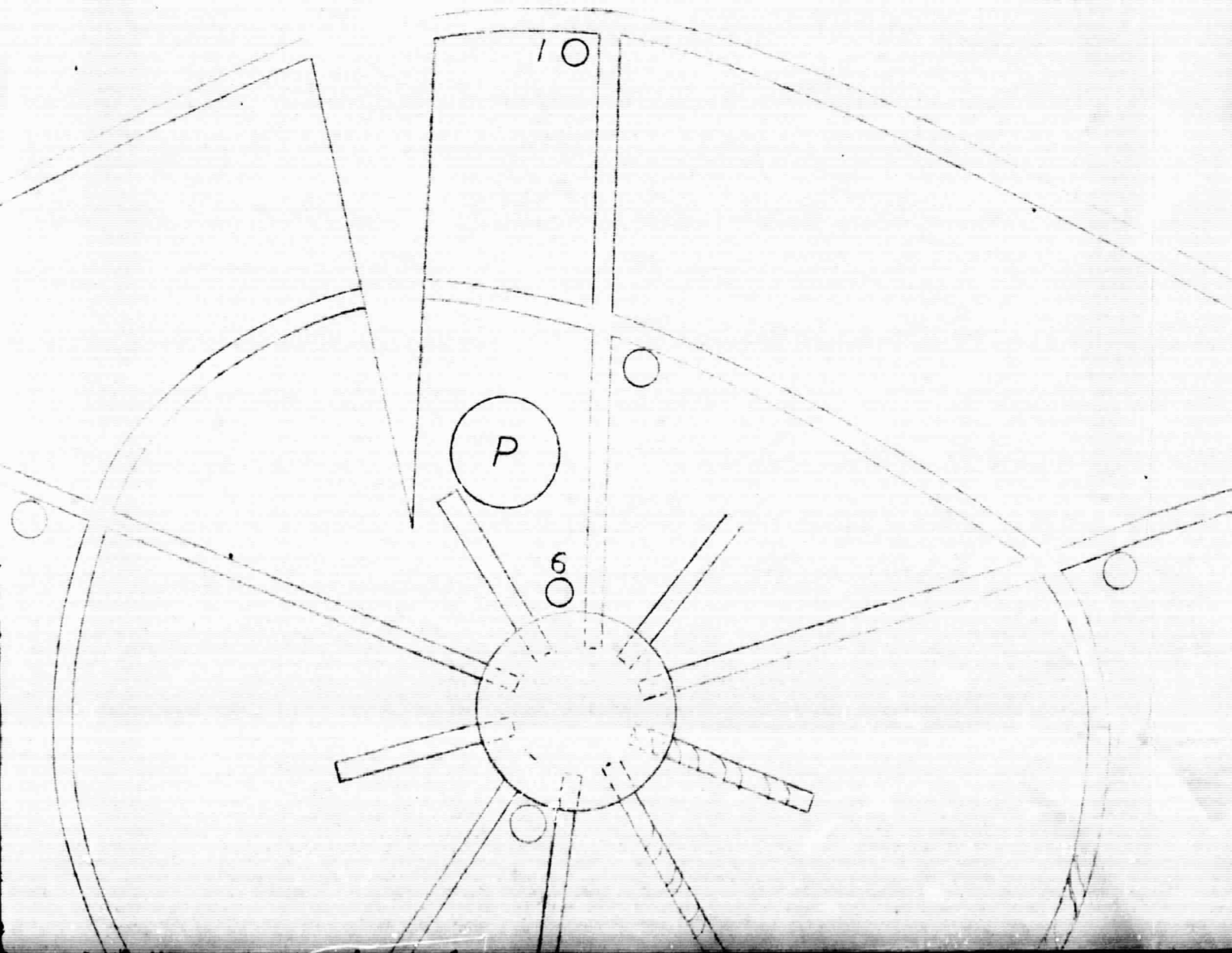
Appendix F
PATTERNS

The patterns used for the patches on the ECGS are presented in a pocket inside the back cover of this volume.

FOLDOUT FRAME 1

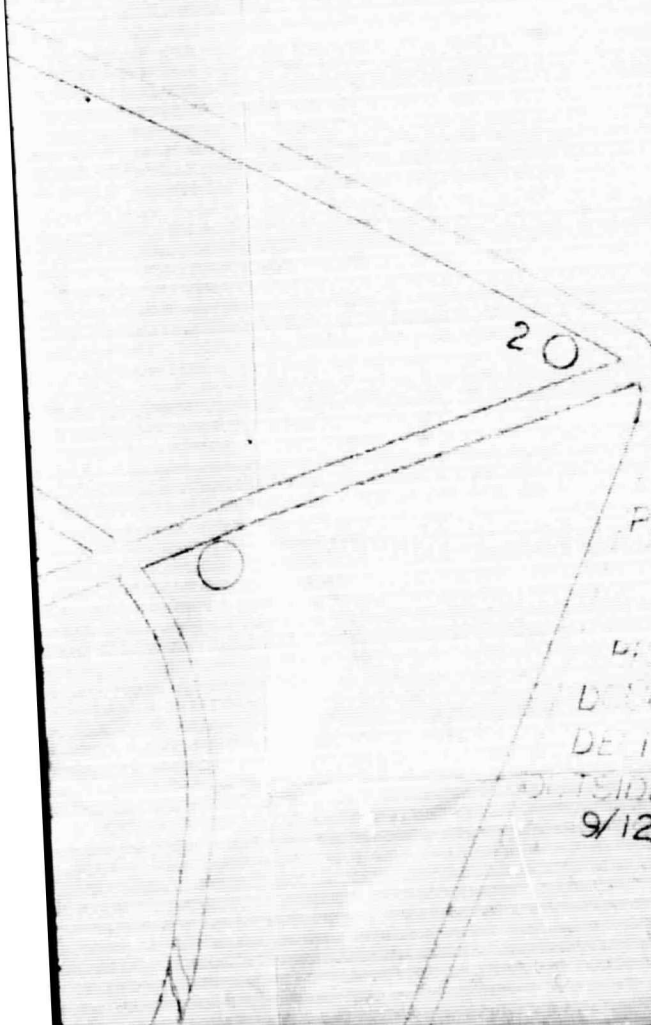


FOLDOUT FRAME 2

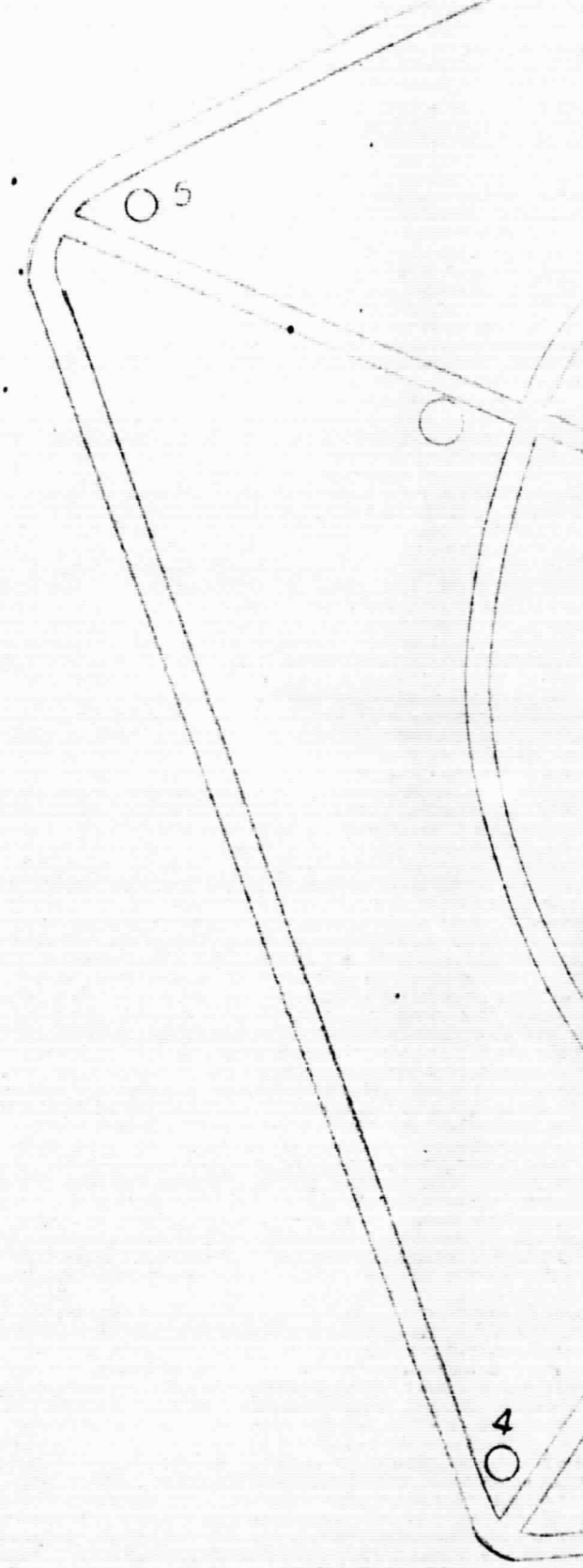


FOLDOUT FRAME 3

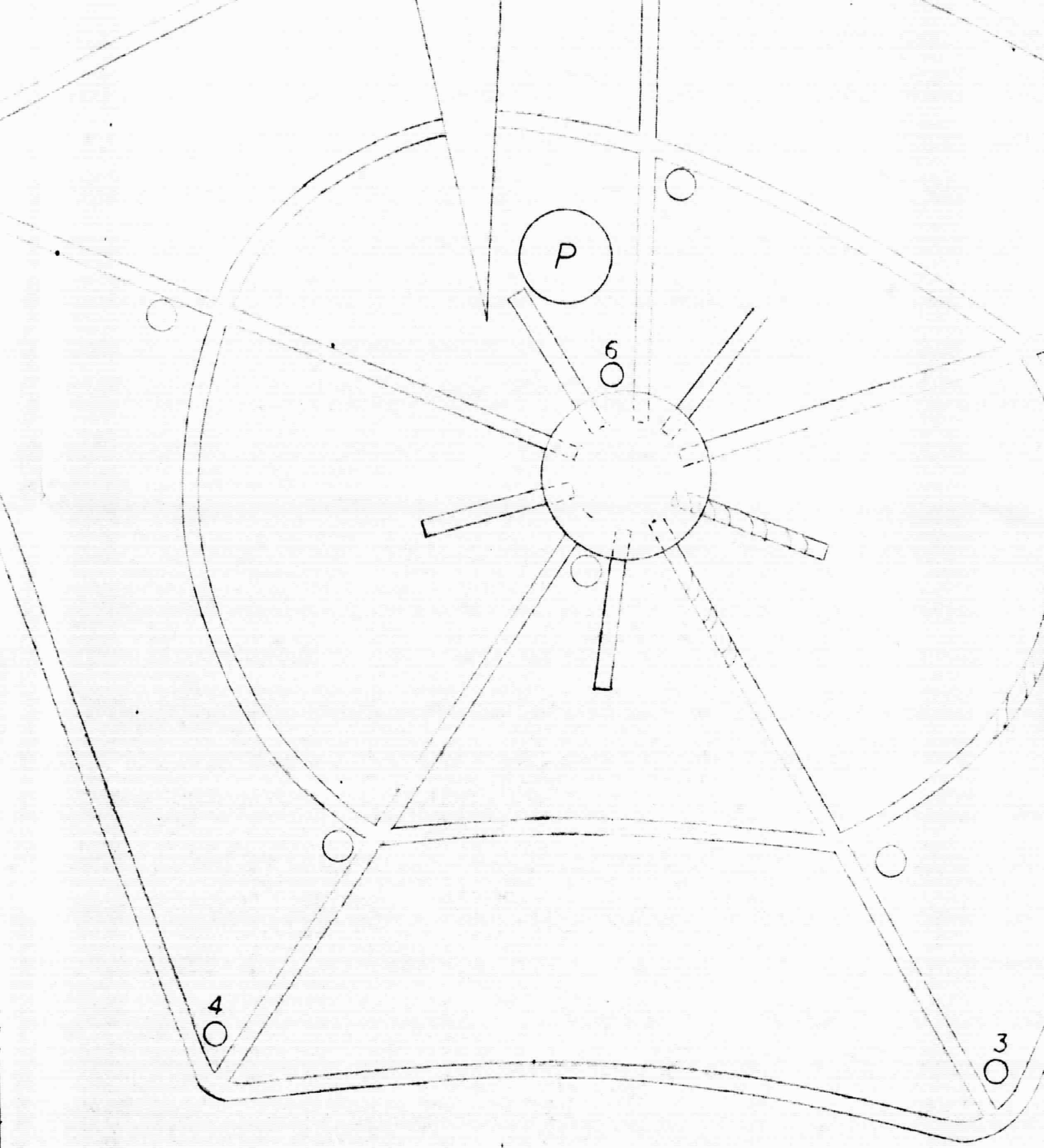
*1 PATTERN OF 3 PCS.

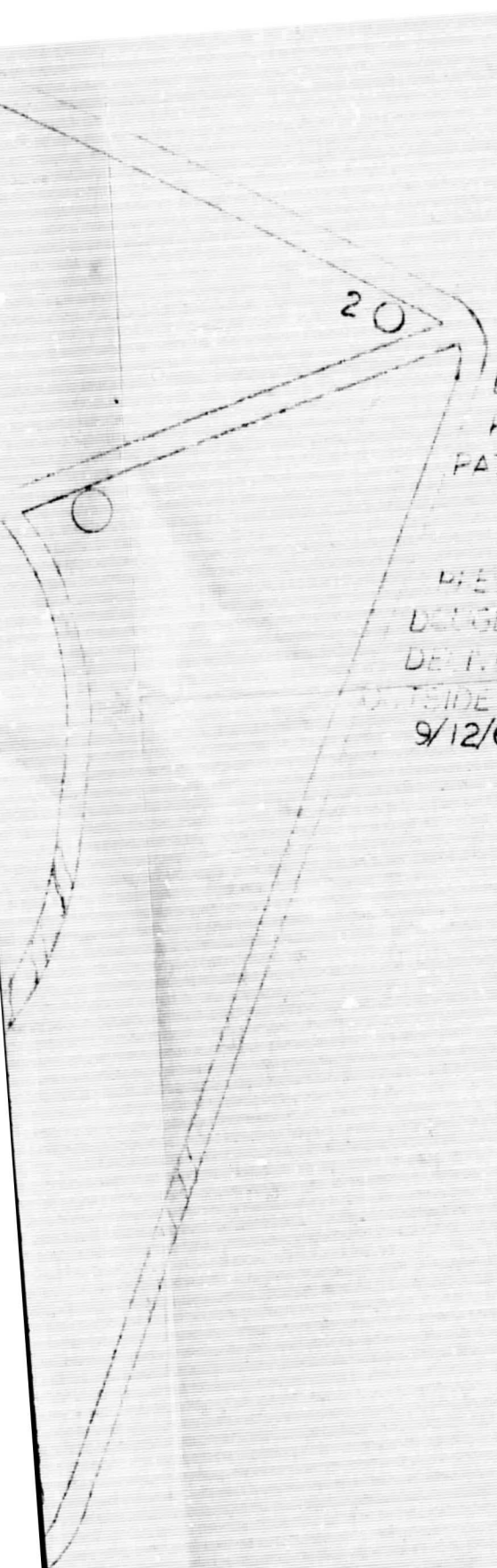


LOWER LEFT ARM
PATCH #14-0301-02-09-01
PATTERN FOR: STEAM RETURN LINES
SPIRAP-PERIPHERAL STEAM
LINE 1/8" SPIRAP
PRESSURE LINES (E) 1-2-3-4-5-6
DOUGLAS "2-1/2" VACUUM CONNECTION
DELIVERY SUIT
OUTSIDE OF PATCH
9/12/67



FOLDOUT FRAME 4

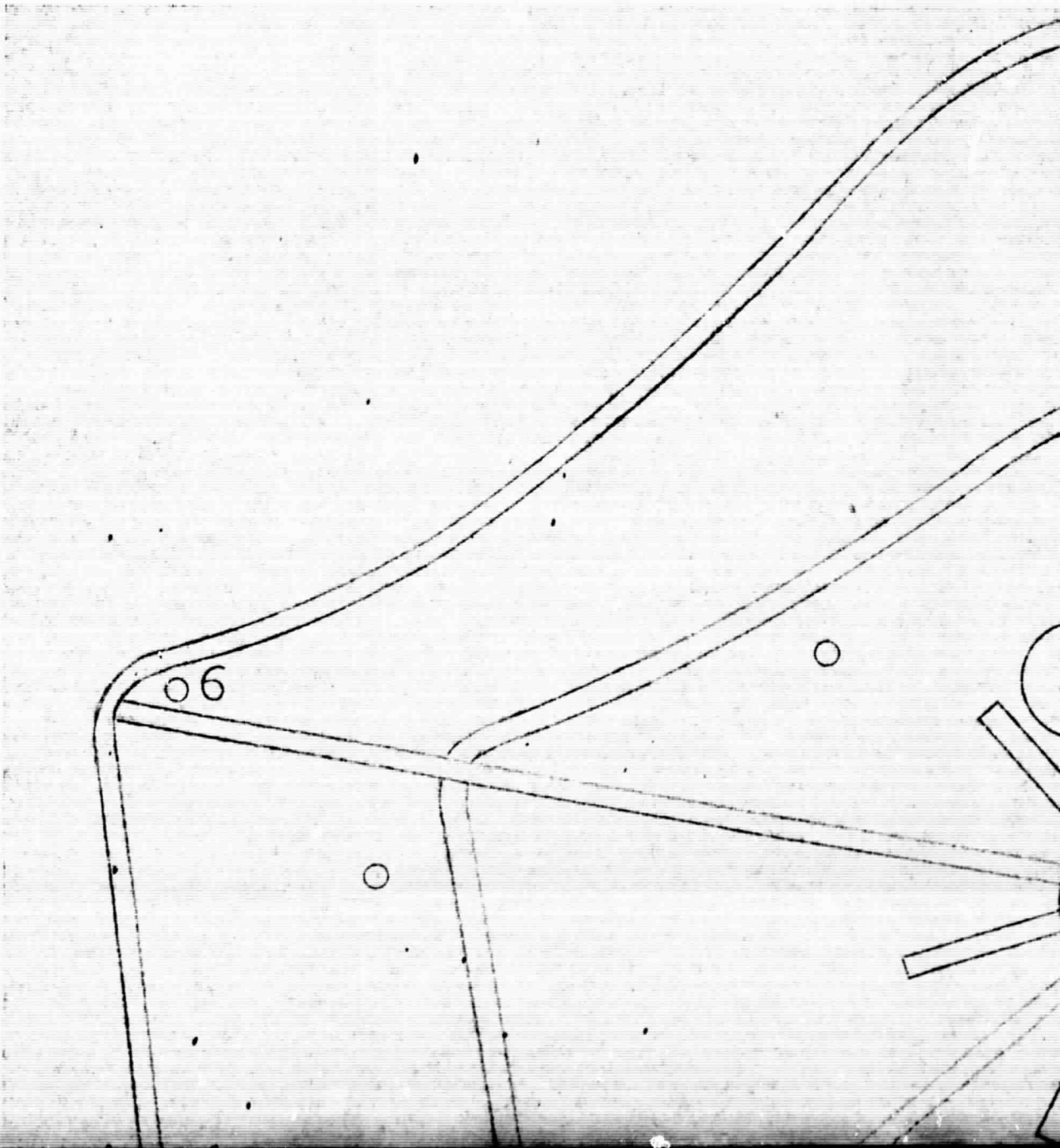

P
6
4
3



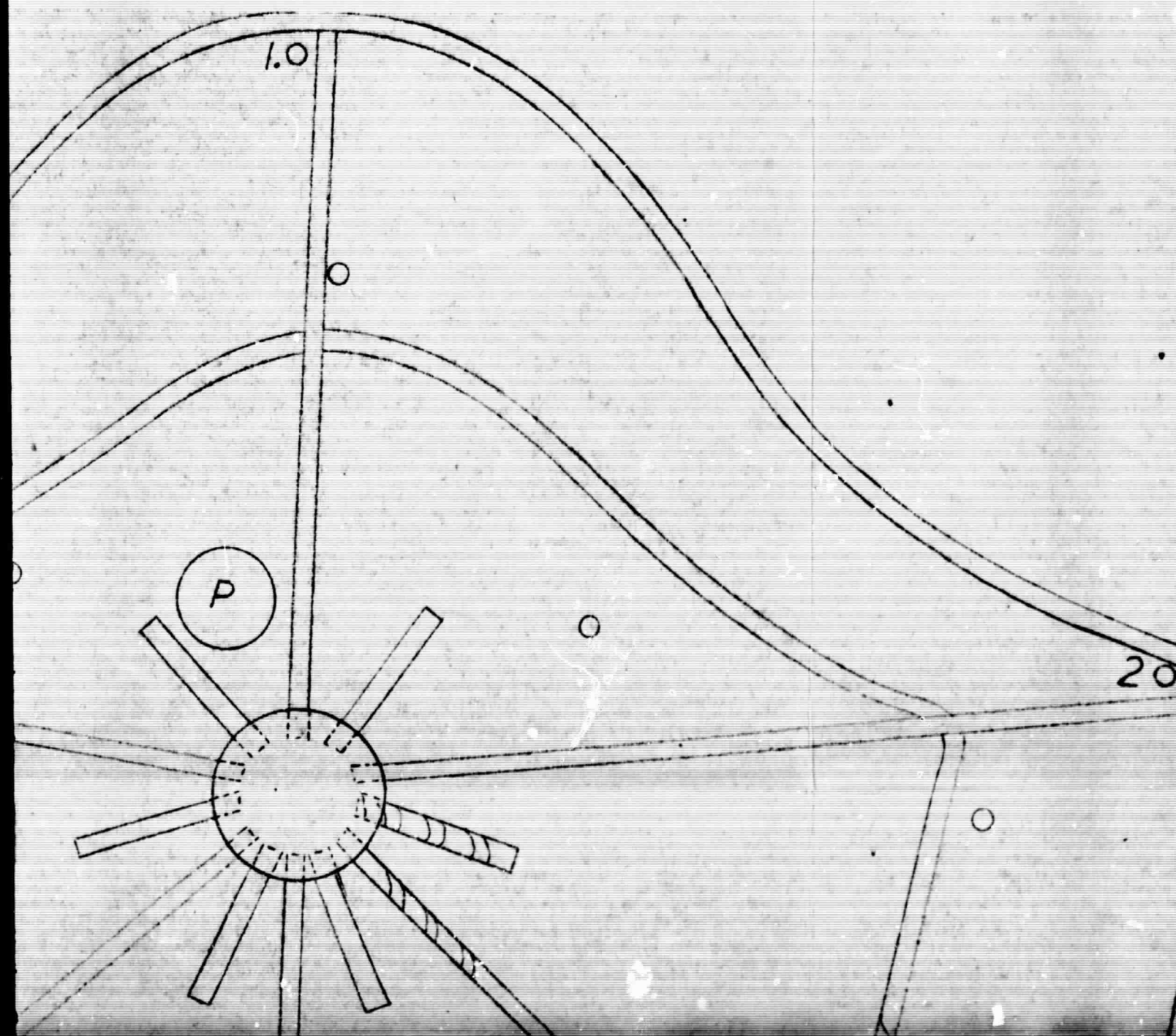
LOWER LEFT ARM
PATCH #14-0301-02-09-01
PATTERN FOR: STEAM RETURN LINES
SPIRAP-PERIPHERAL STEAM
LINE ⅛" SPIRAP
PRESSURE LINES (6) 1-2-3-4-5-6
DOUGLAS #2-½" VACUUM CONNECTION
DELIVERY SUIT
OUTSIDE OF PATCH
9/12/67

FOLDOUT FRAME 6

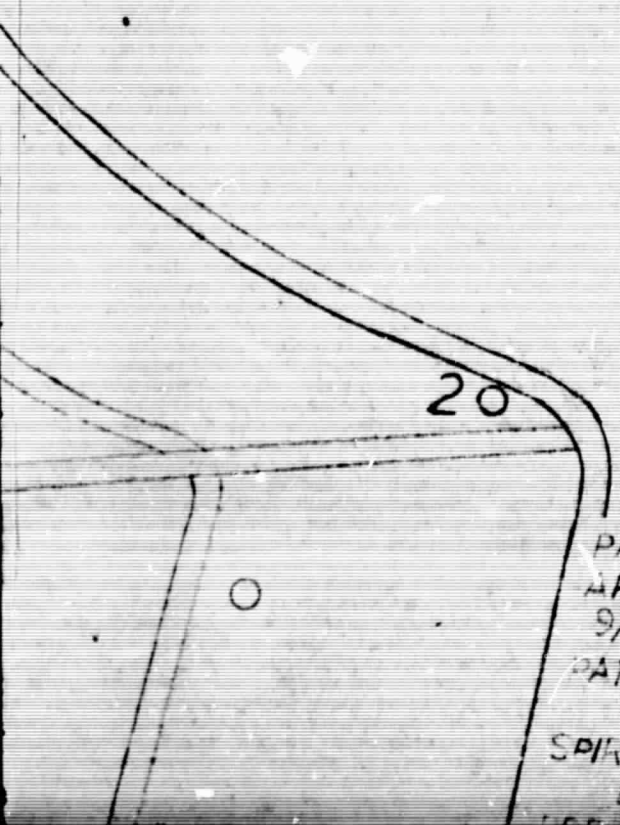
FOLDOUT FRAME 1



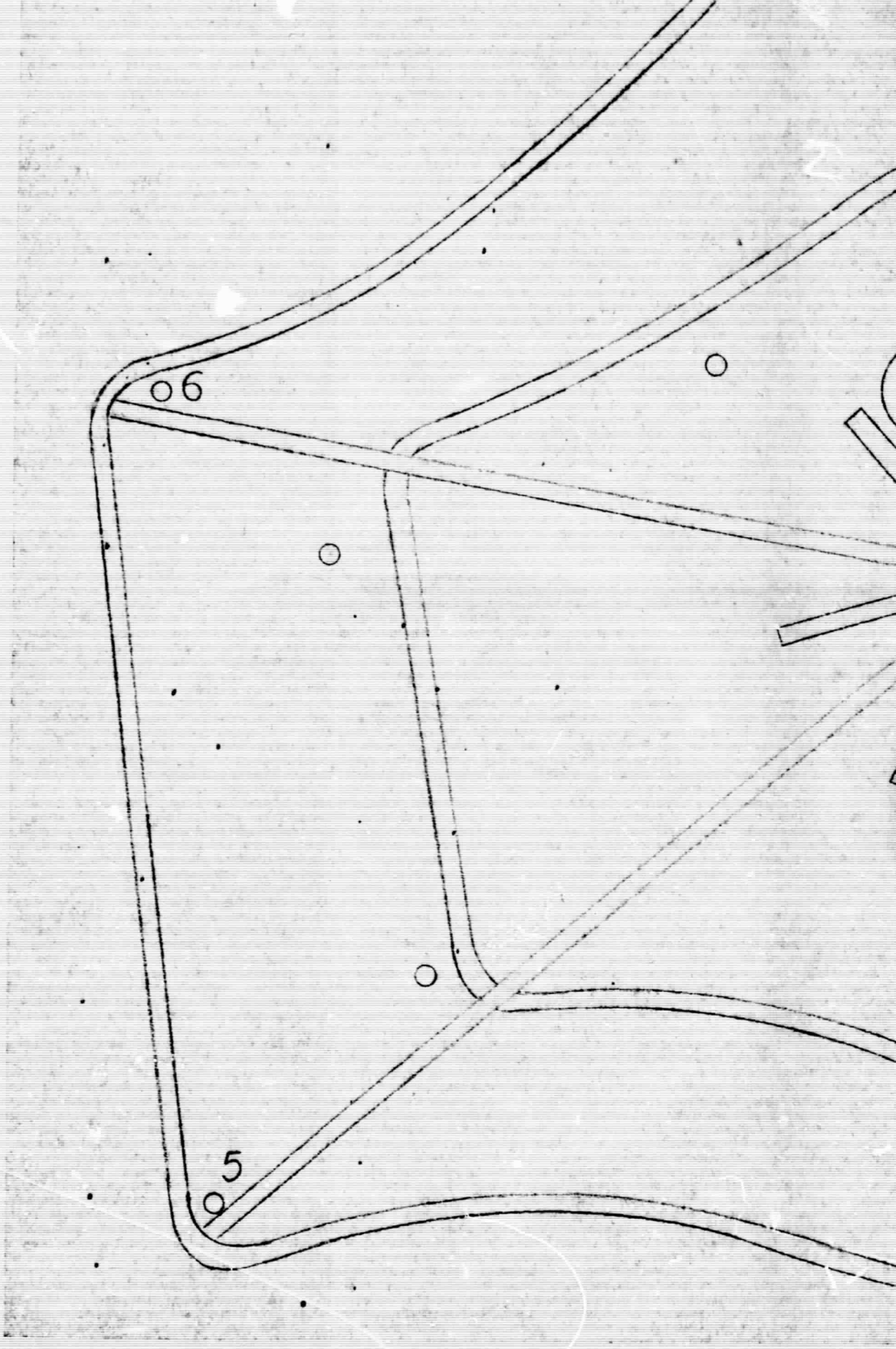
FOLDOUT FRAME 2



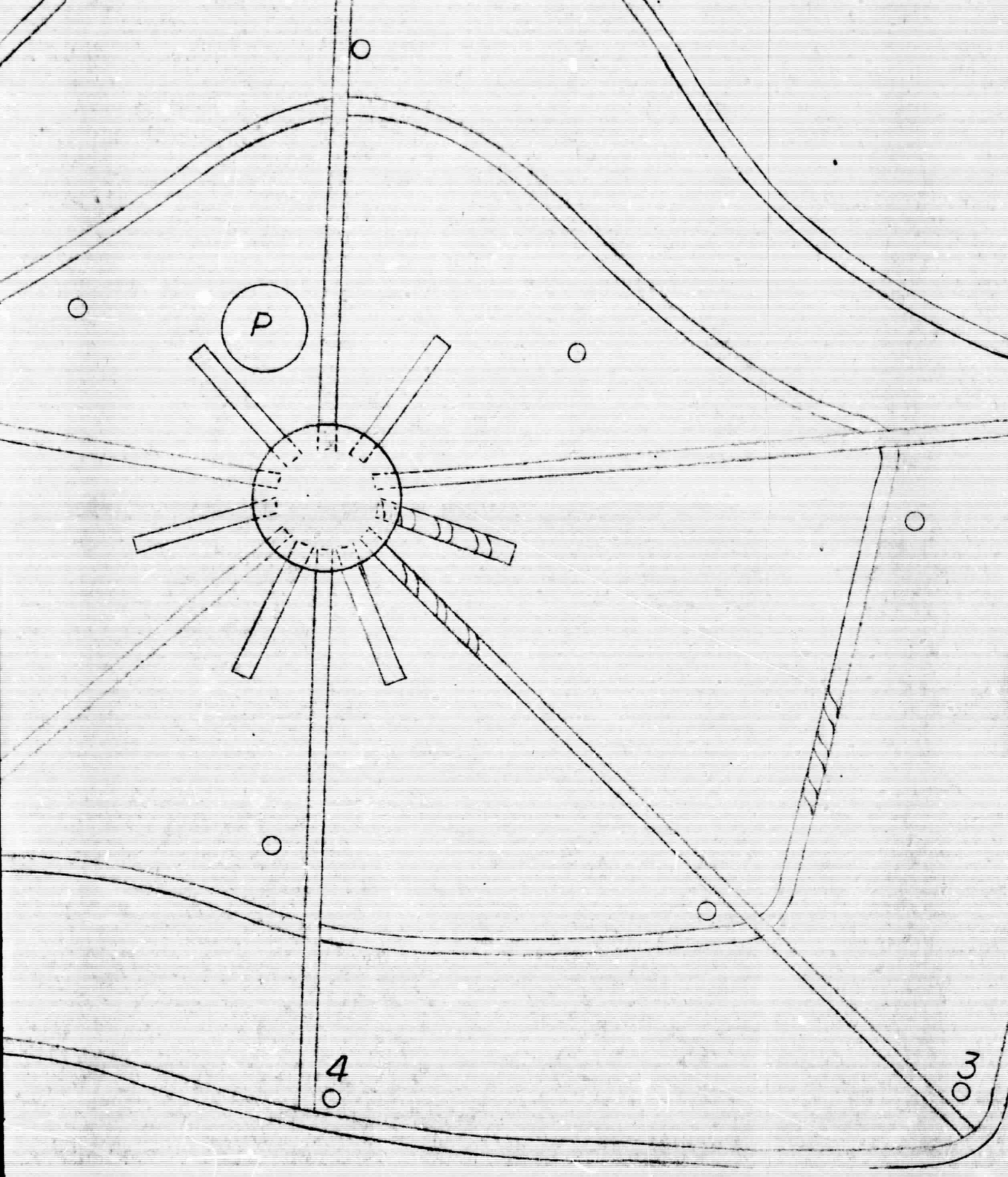
FOLDOUT FRAME 3



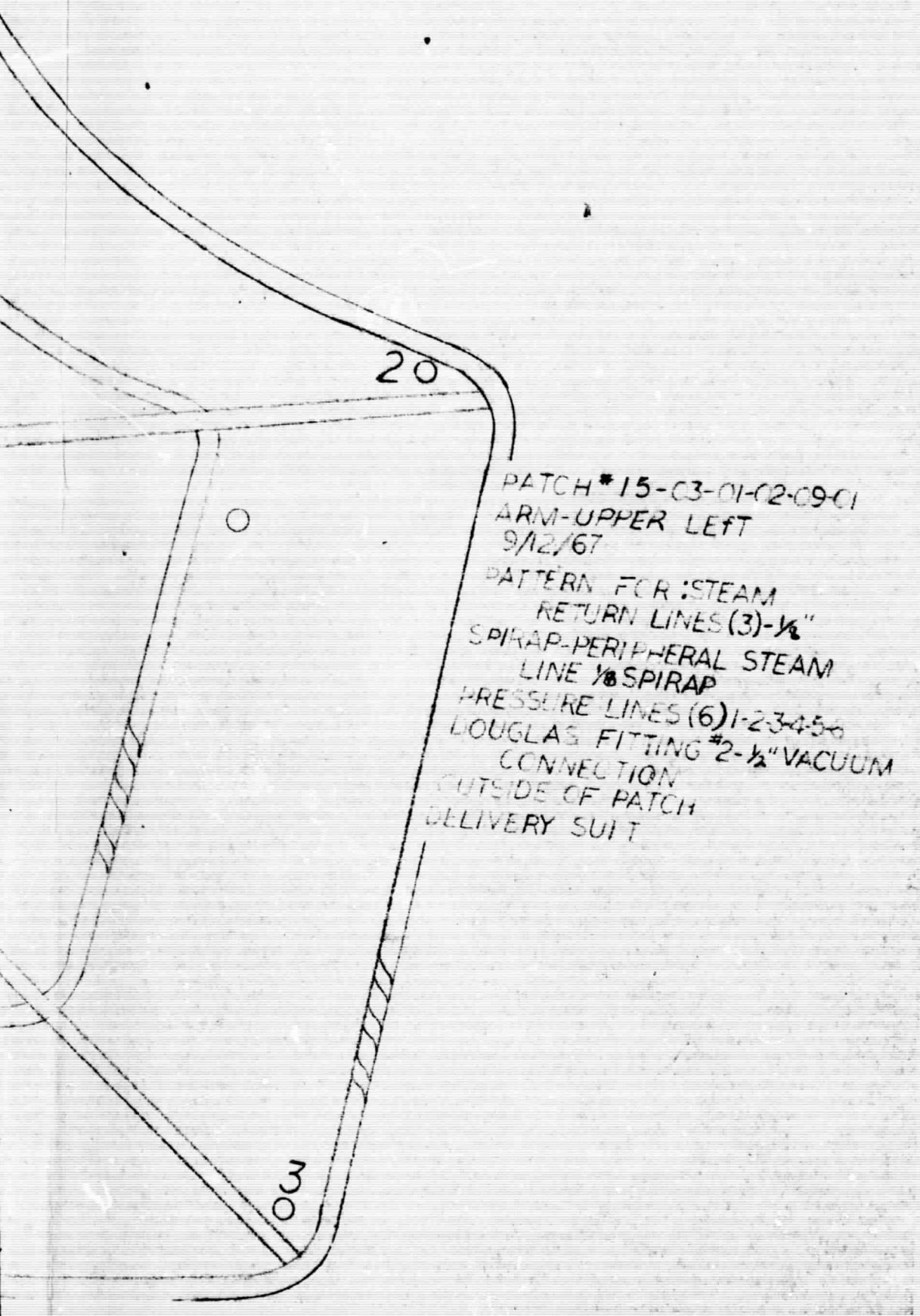
PATCH #15-C3-01-C2-C9-C1
ARM-UPPER LEFT
9/12/67
PATTERN FOR: STEAM
RETURN LINES (3)-½"
SPIRAP-PERIPHERAL STEAM
LINE ½ SPIRAP



FOLDOUT FRAME 4



FOLDOUT FRAME 5



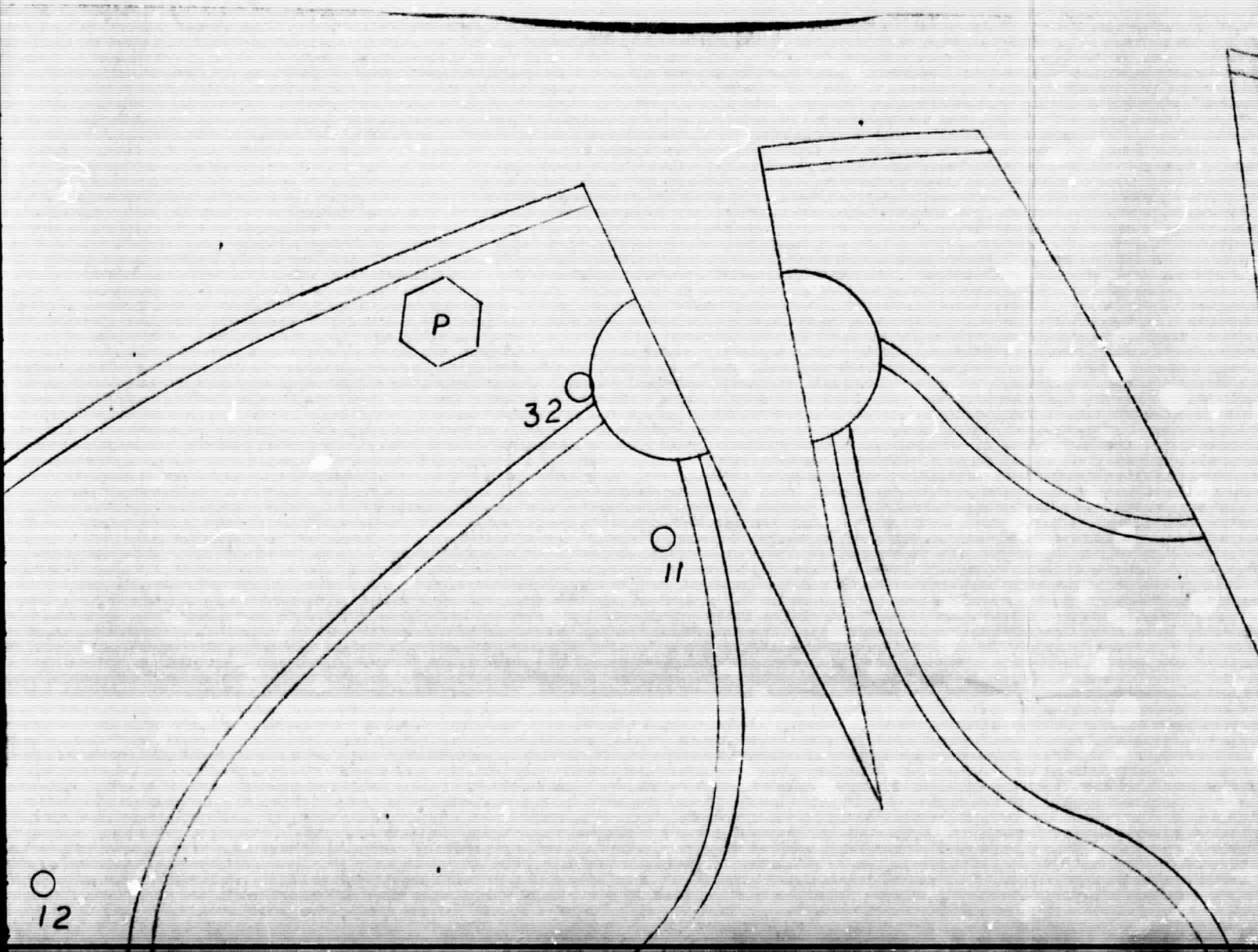
PATCH #15-C3-01-02-09-01
ARM-UPPER LEFT
9/12/67
PATTERN FOR: STEAM
RETURN LINES (3)-⅛"
SPIRAP-PERIPHERAL STEAM
LINE ⅛ SPIRAP
PRESSURE LINES (6) 1-2-3-4-5-6
DOUGLAS FITTING #2-½" VACUUM
CONNECTION
OUTSIDE OF PATCH
DELIVERY SUIT

FOLDOUT FRAME 6

FOLDOUT FRAME

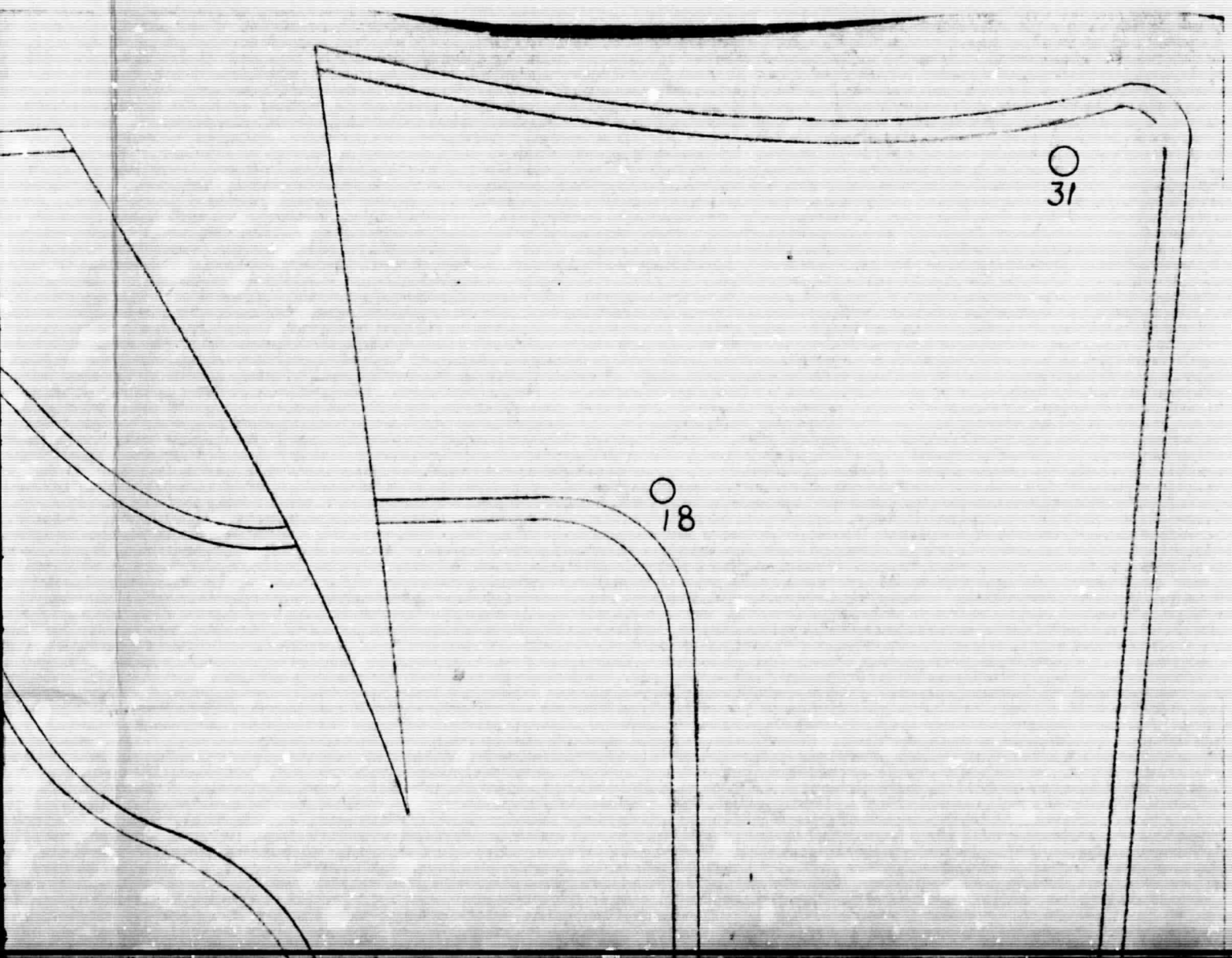


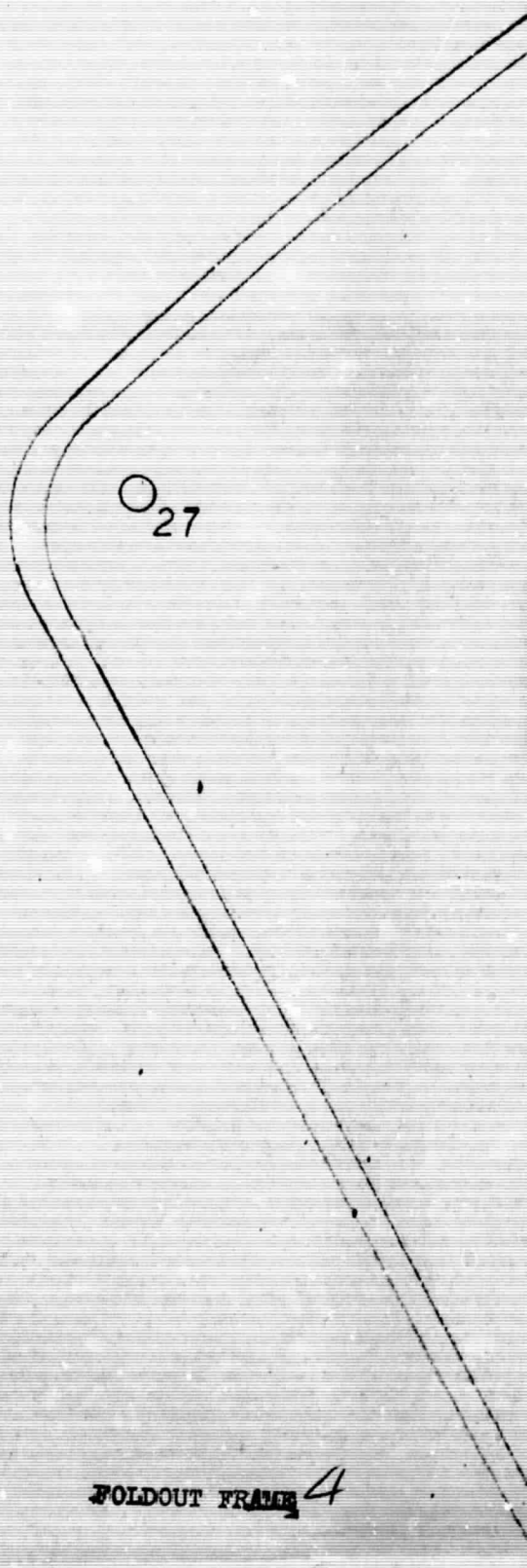
FOLDOUT FRAME 2



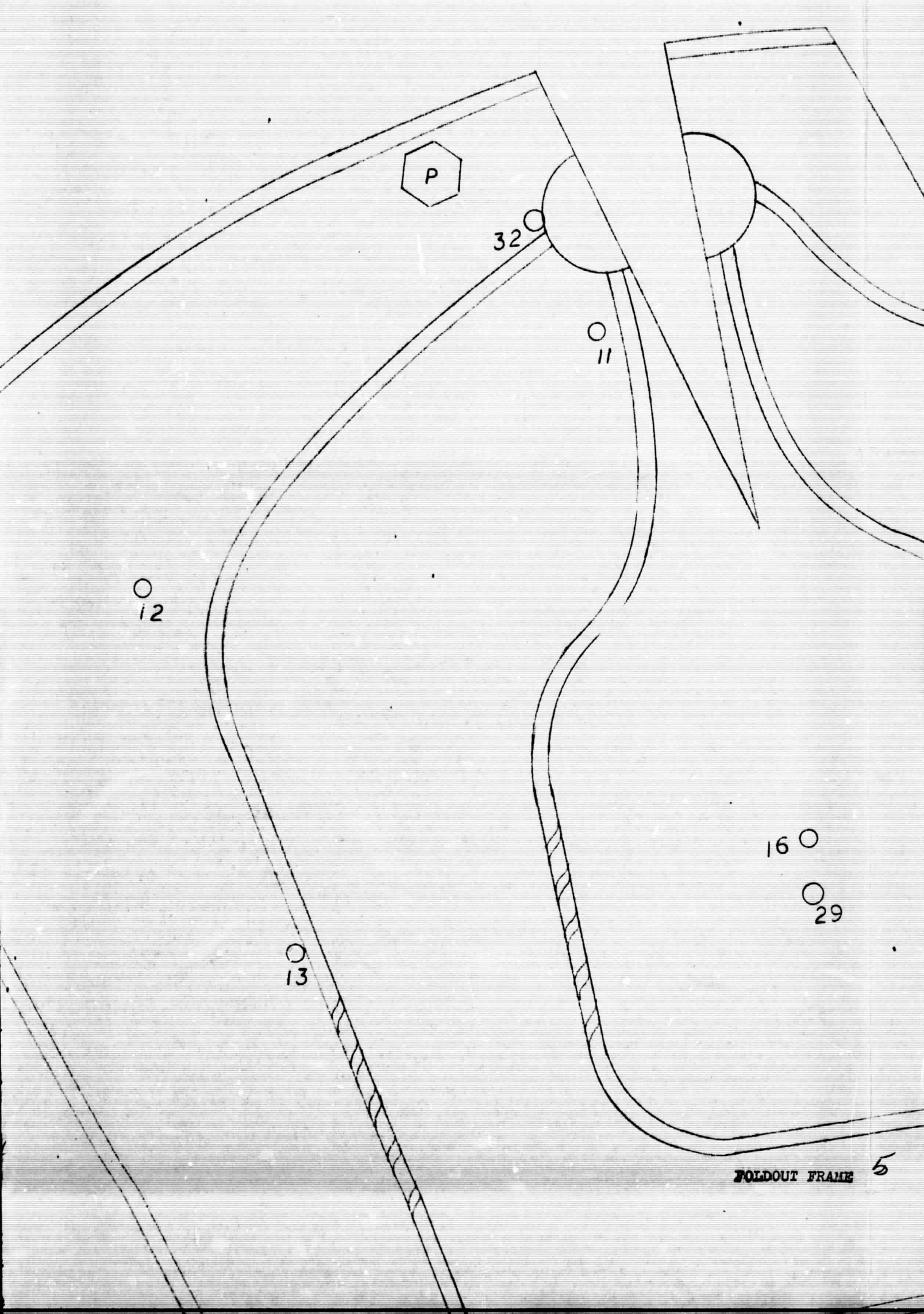
AME 2

FOLDOUT FRAME 3

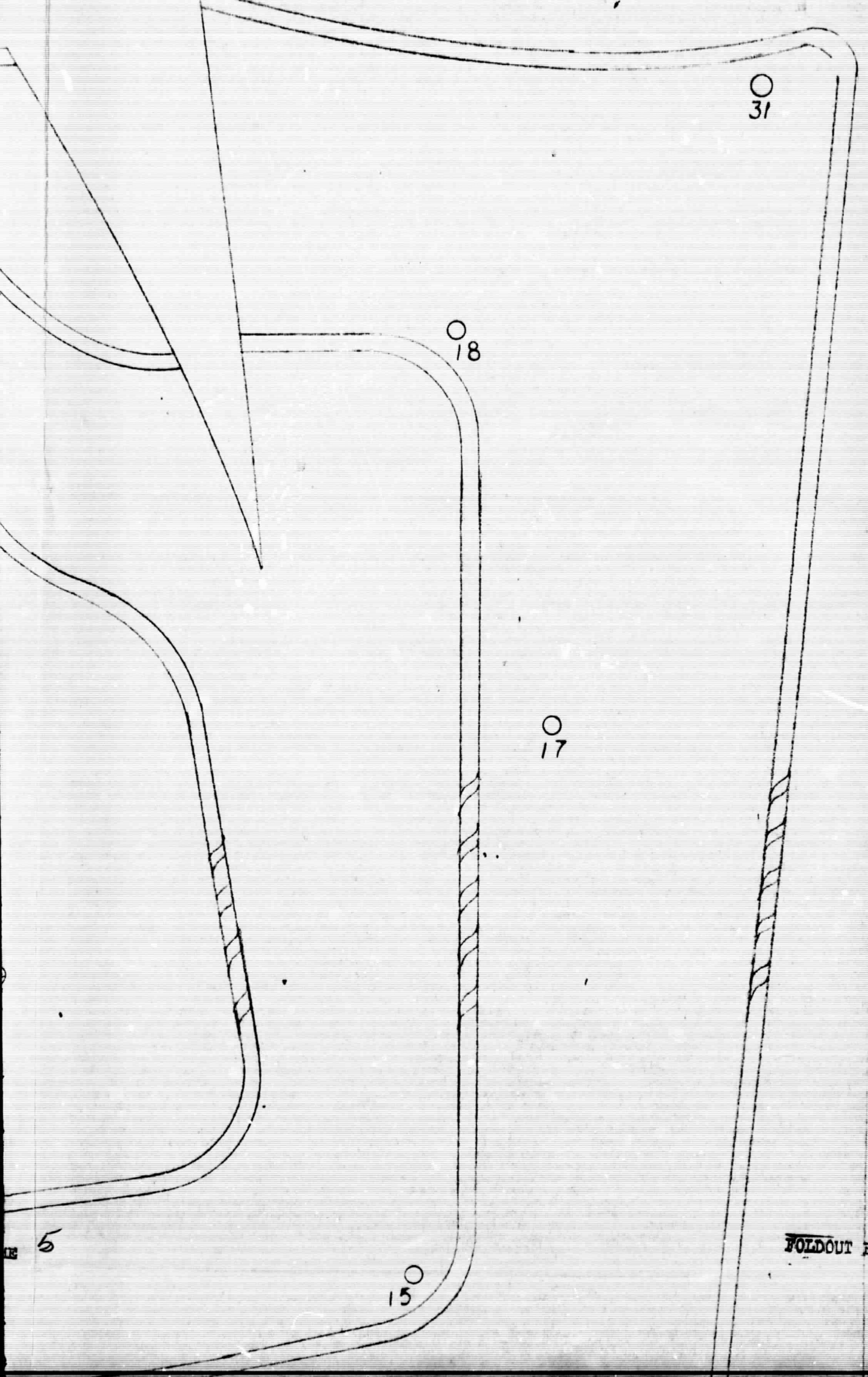




FOLDOUT FRAME 4



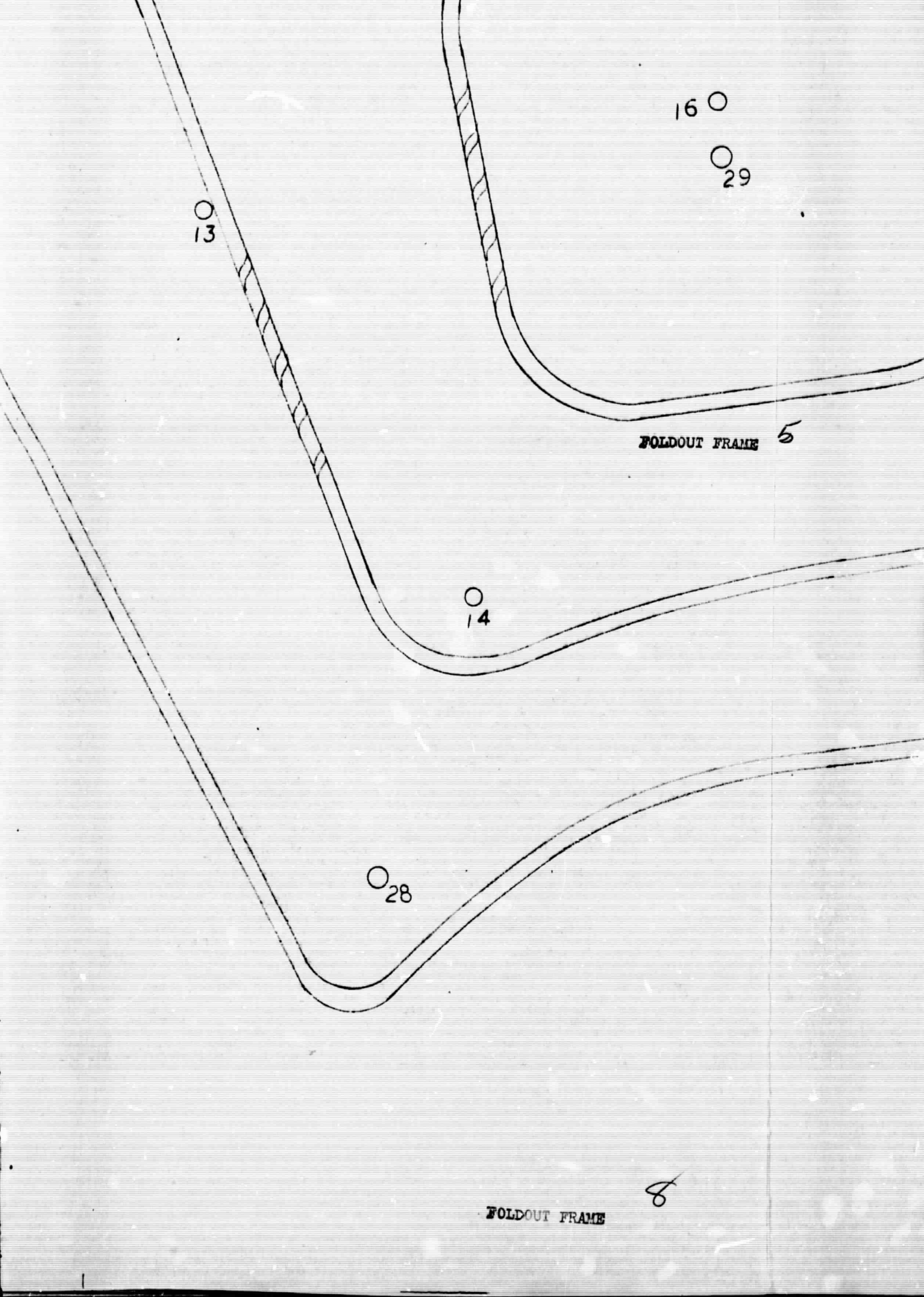
FOLDOUT FRAME 5

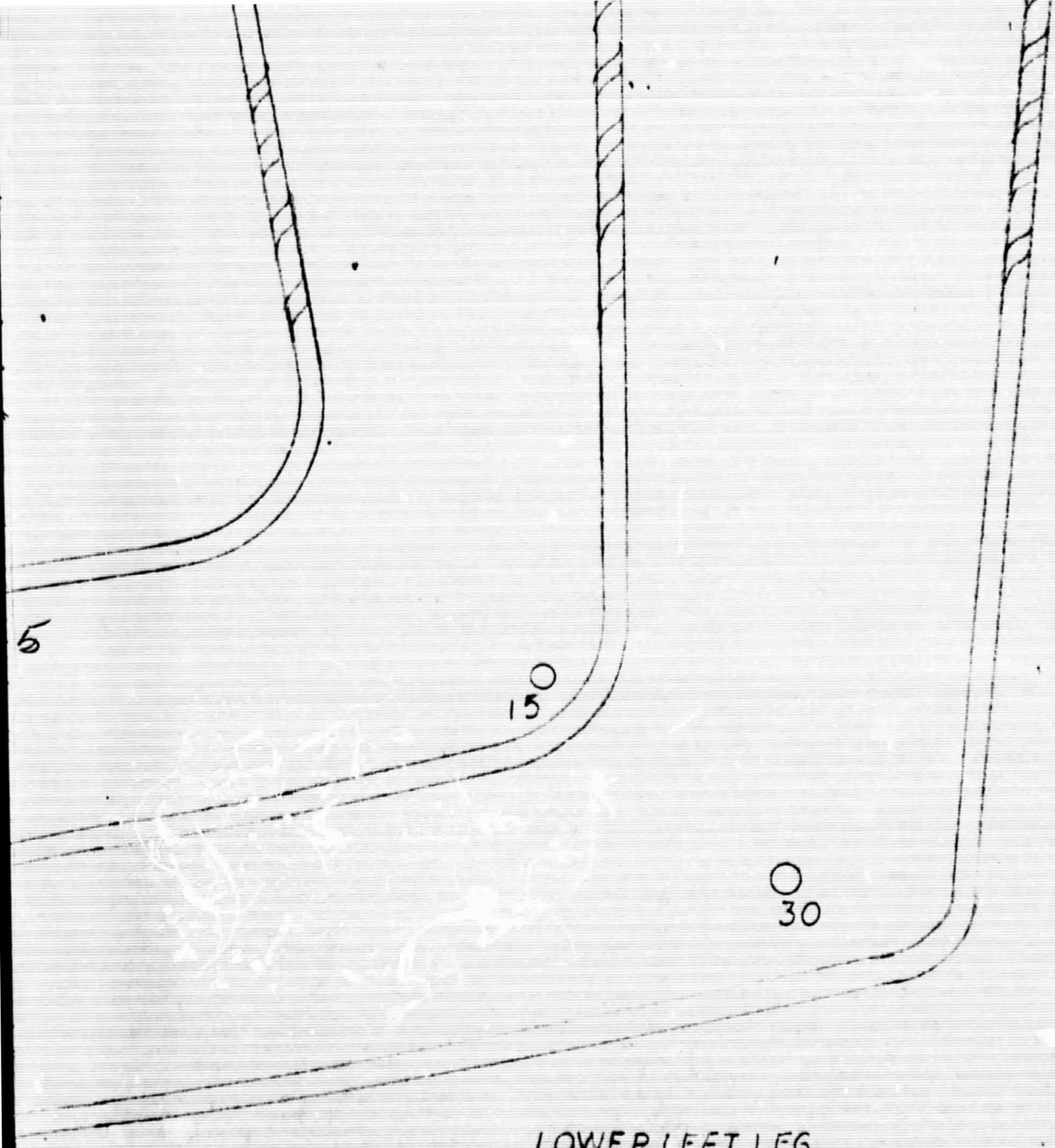


FOLDOUT FRAME

FOLDOUT FRAME 4

FOLDOUT FRAME 7


16
29
13
FOLDOUT FRAME
5
14
28
8
FOLDOUT FRAME

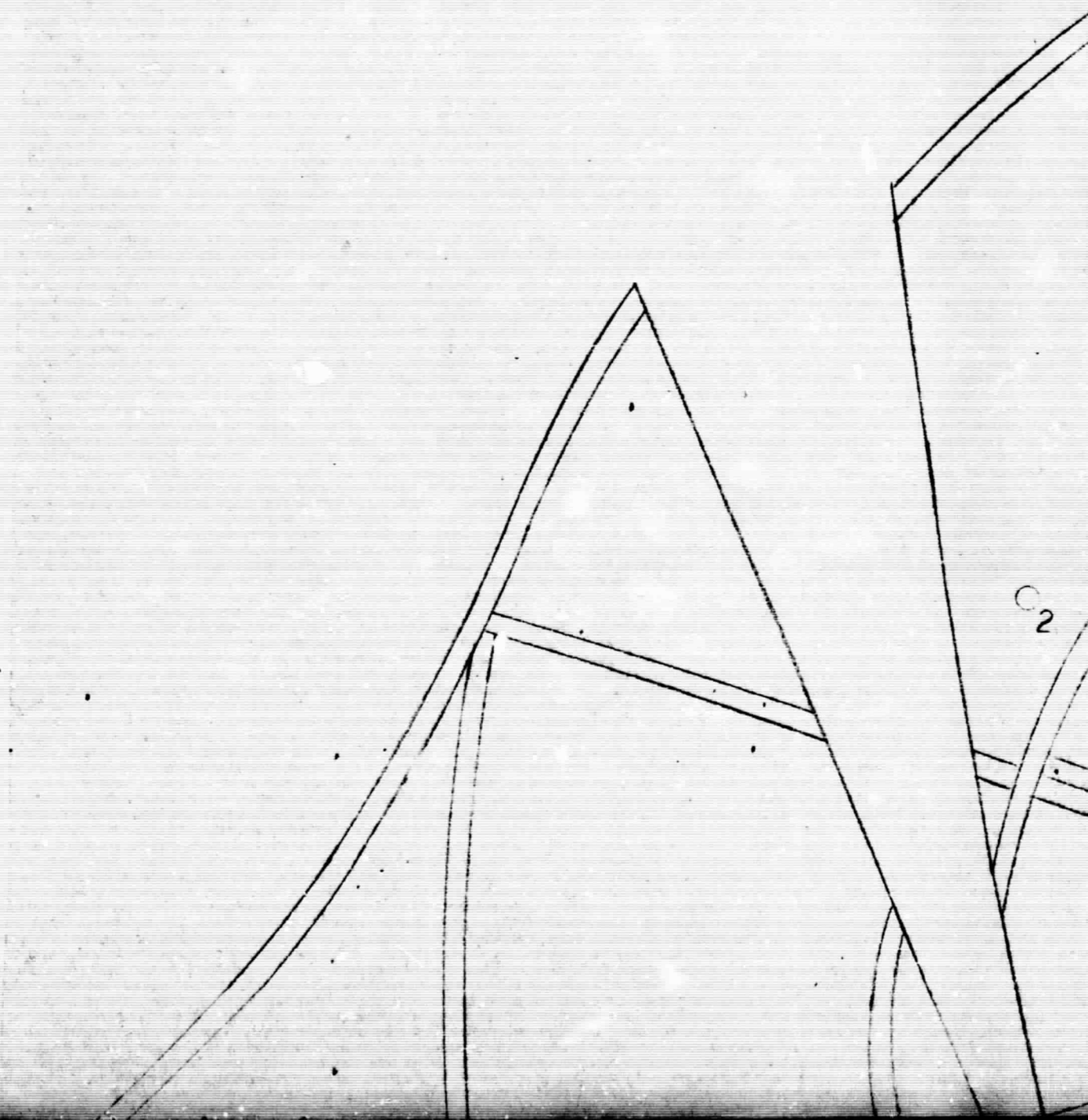


FOLDOUT FRAME 6

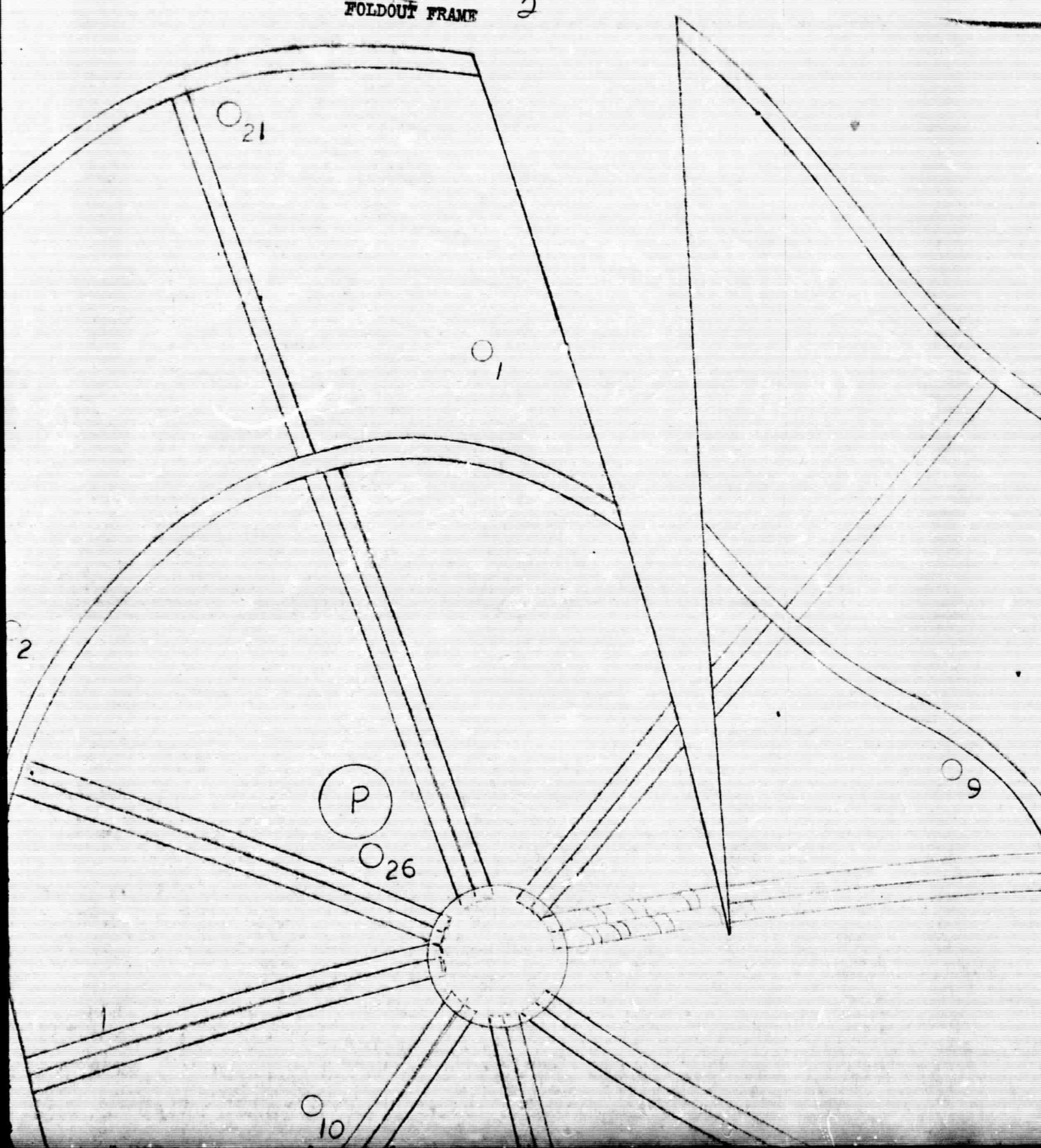
LOWER LEFT LEG
PATCH #07-08-01-01-01-01
PATTERN FOR:
BOILER VOID-6001-1
PRESSURE LINES 27—32
WATER LINES 11—18
OUTSIDE OF PATCH

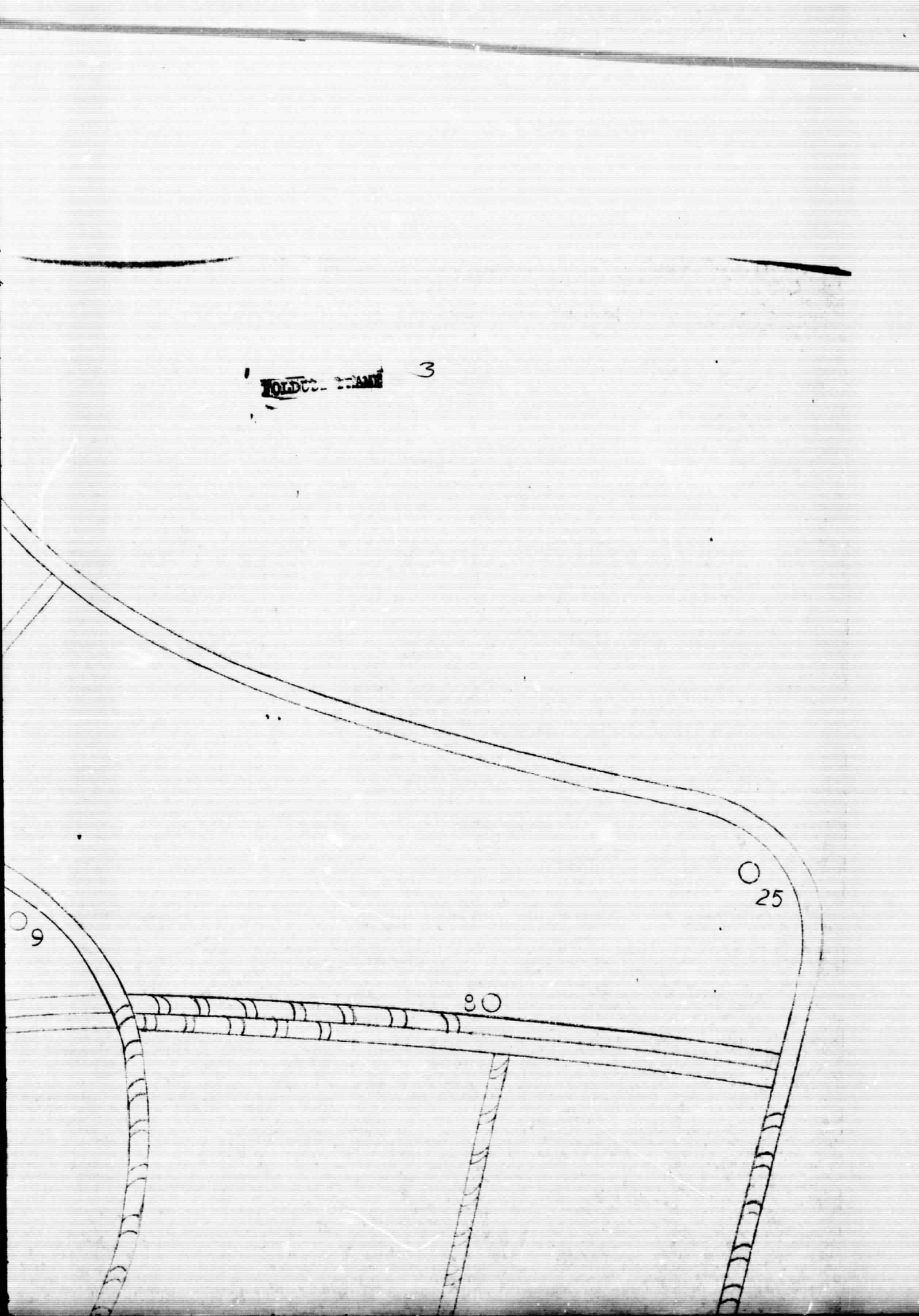
FOLDOUT FRAME 9

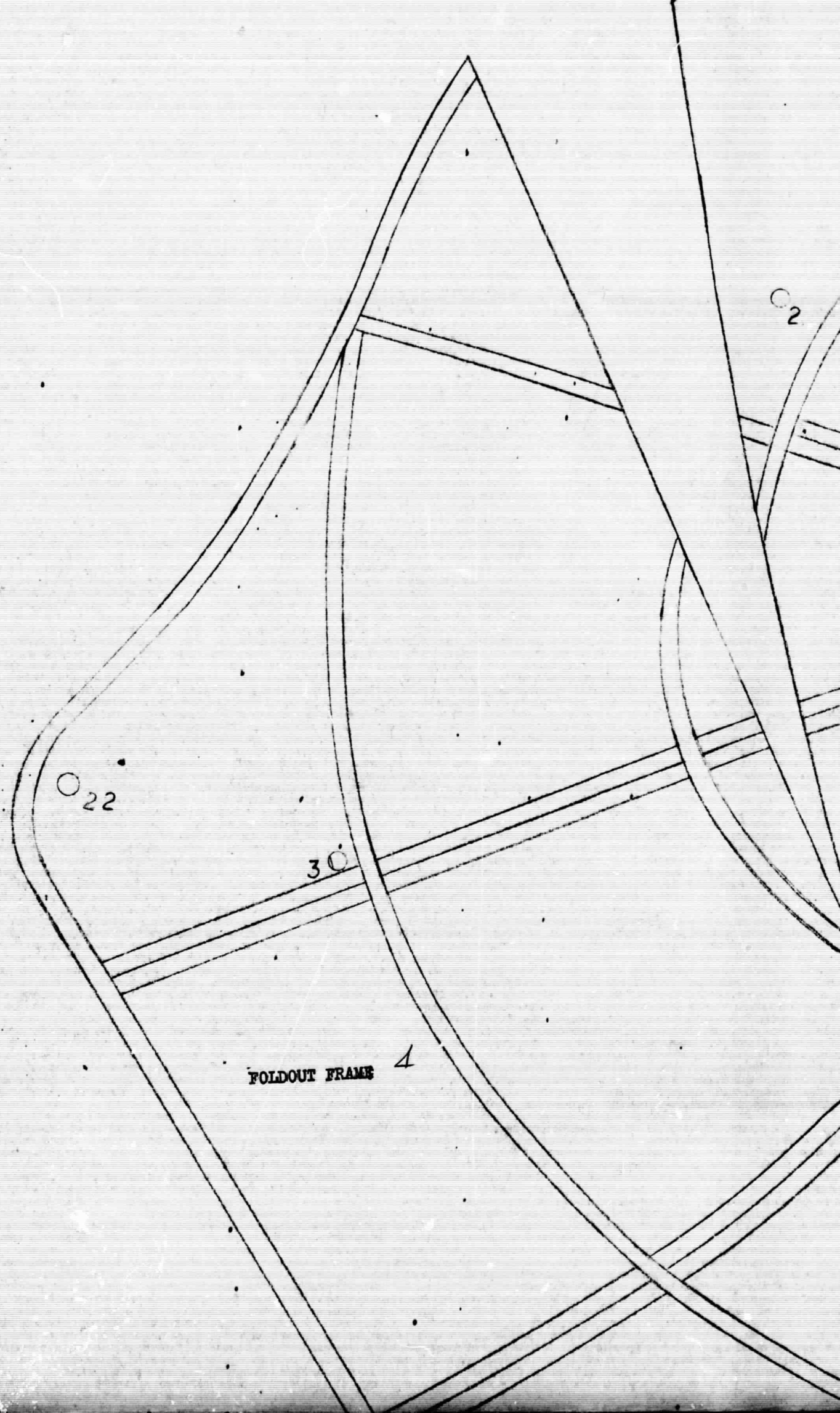
FOLDOUT FRAME

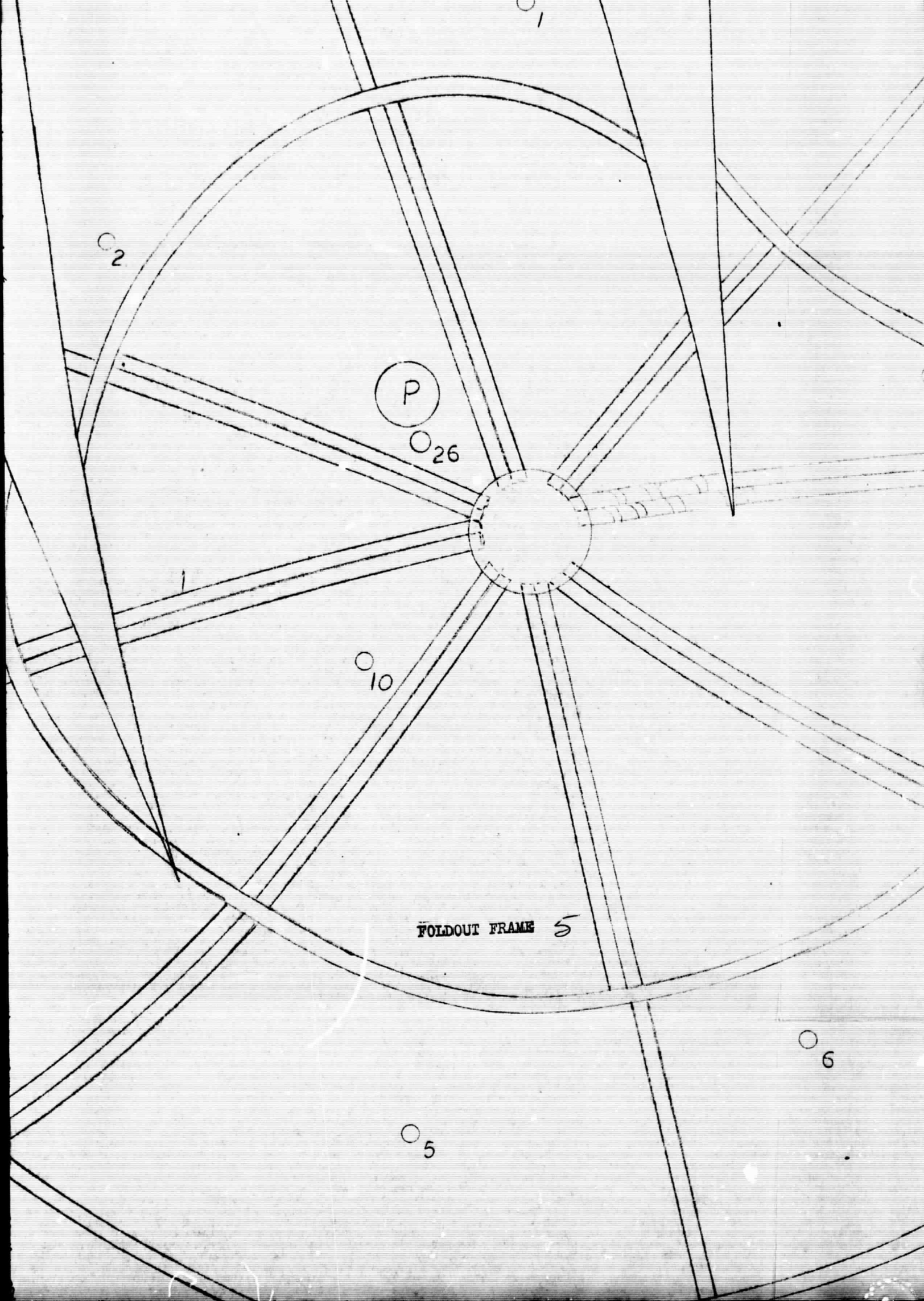


FOLDOUT FRAME 2

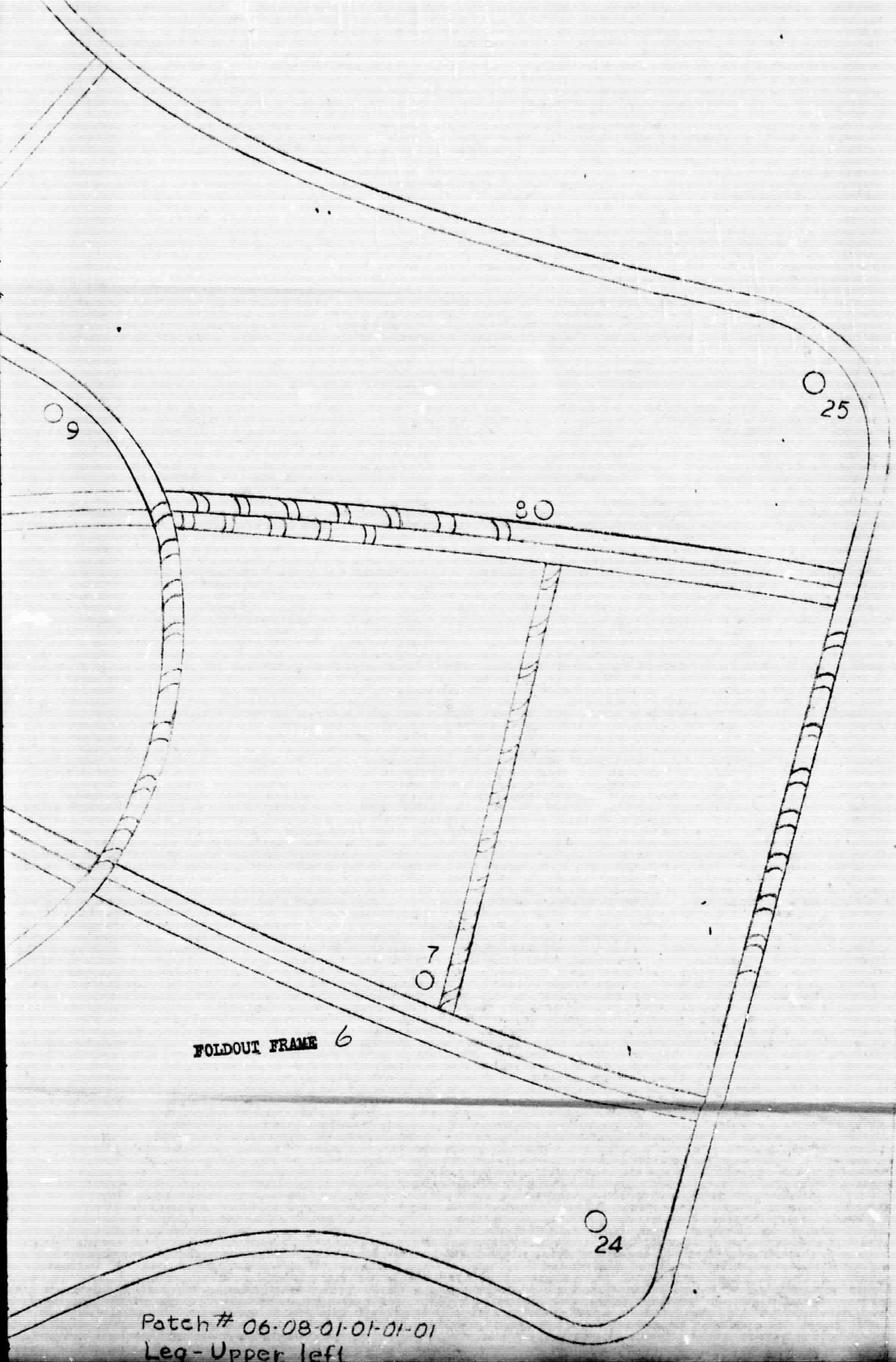



25
9
80

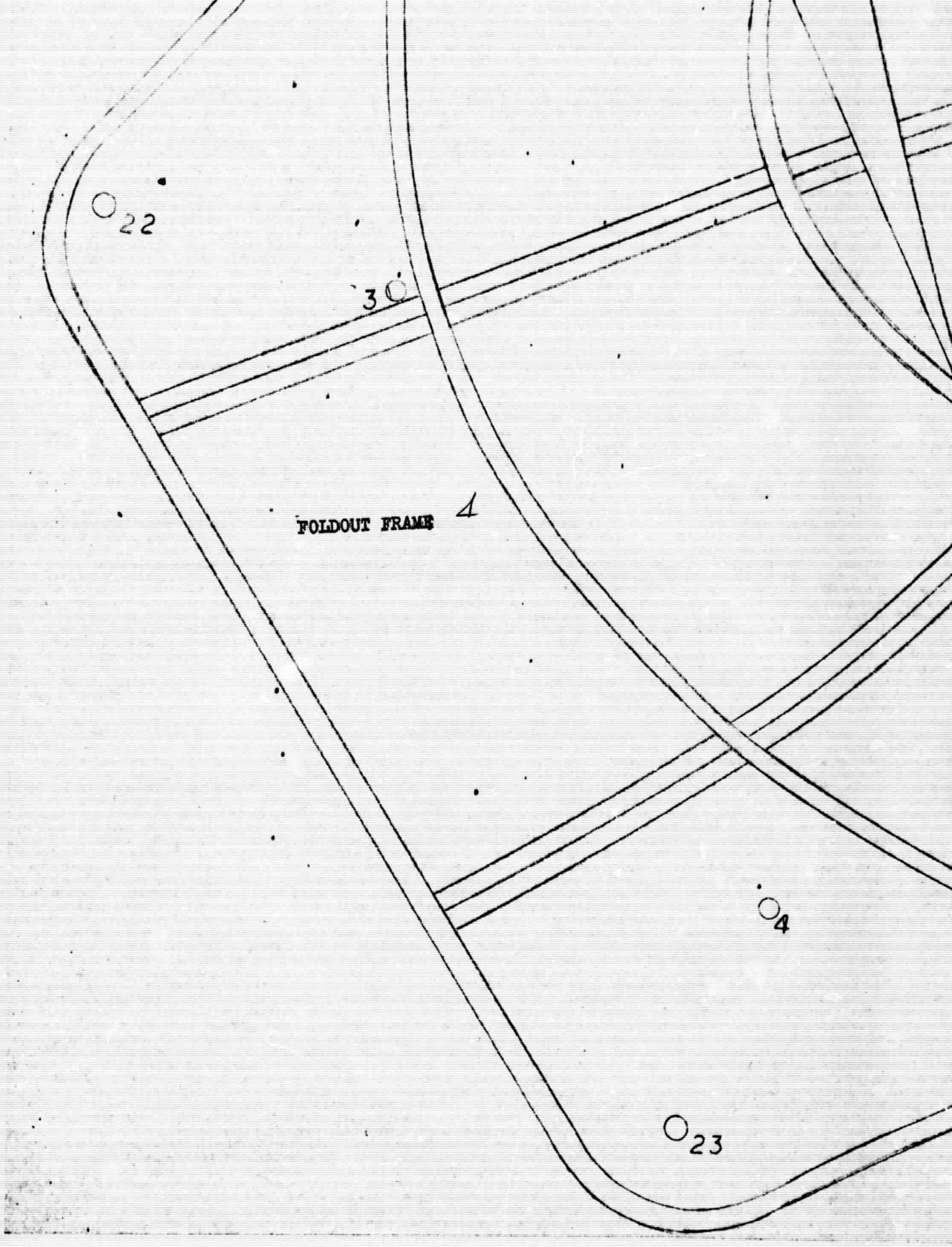

C2
C22
30
FOLDOUT FRAME 4



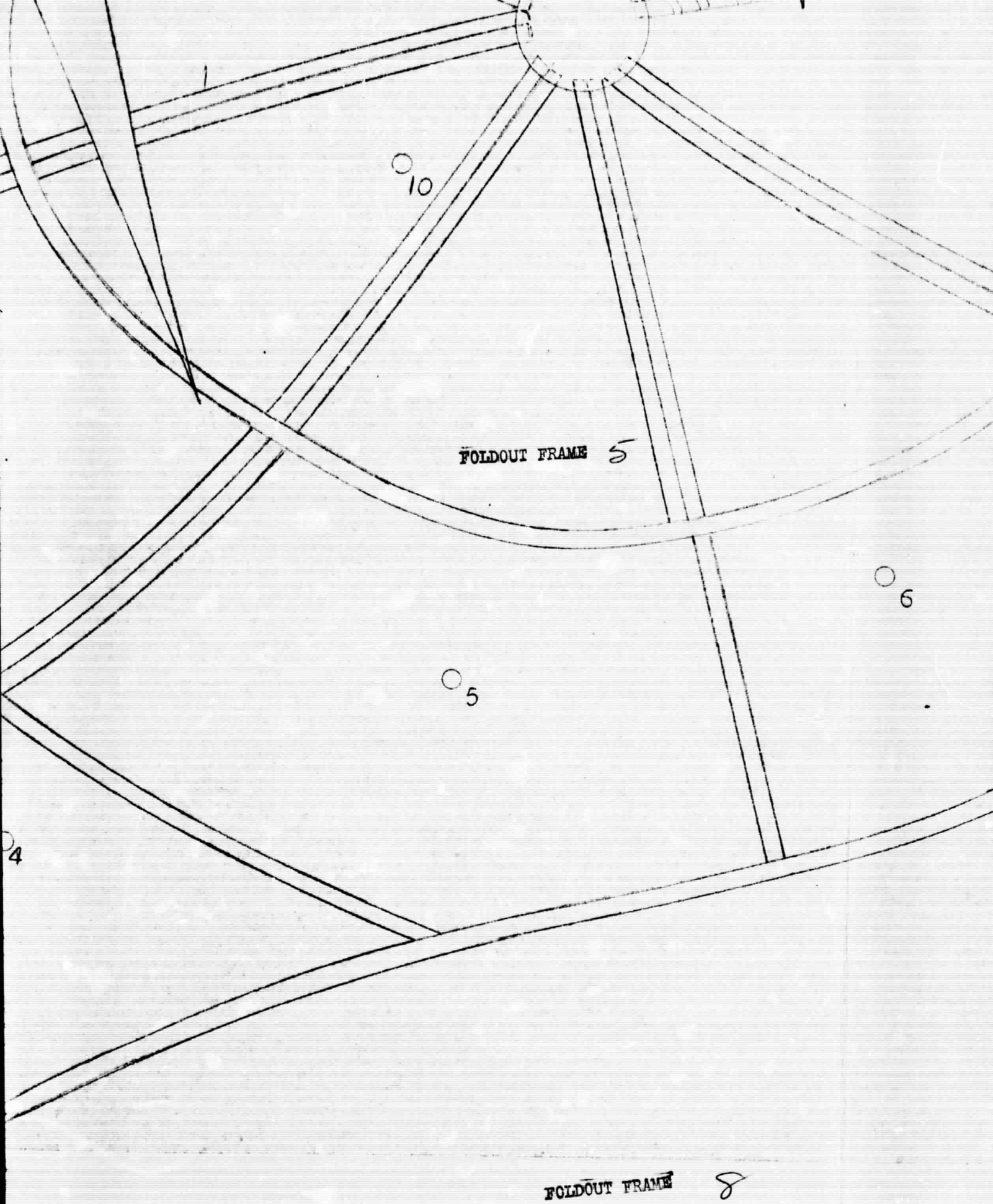
FOLDOUT FRAME 5

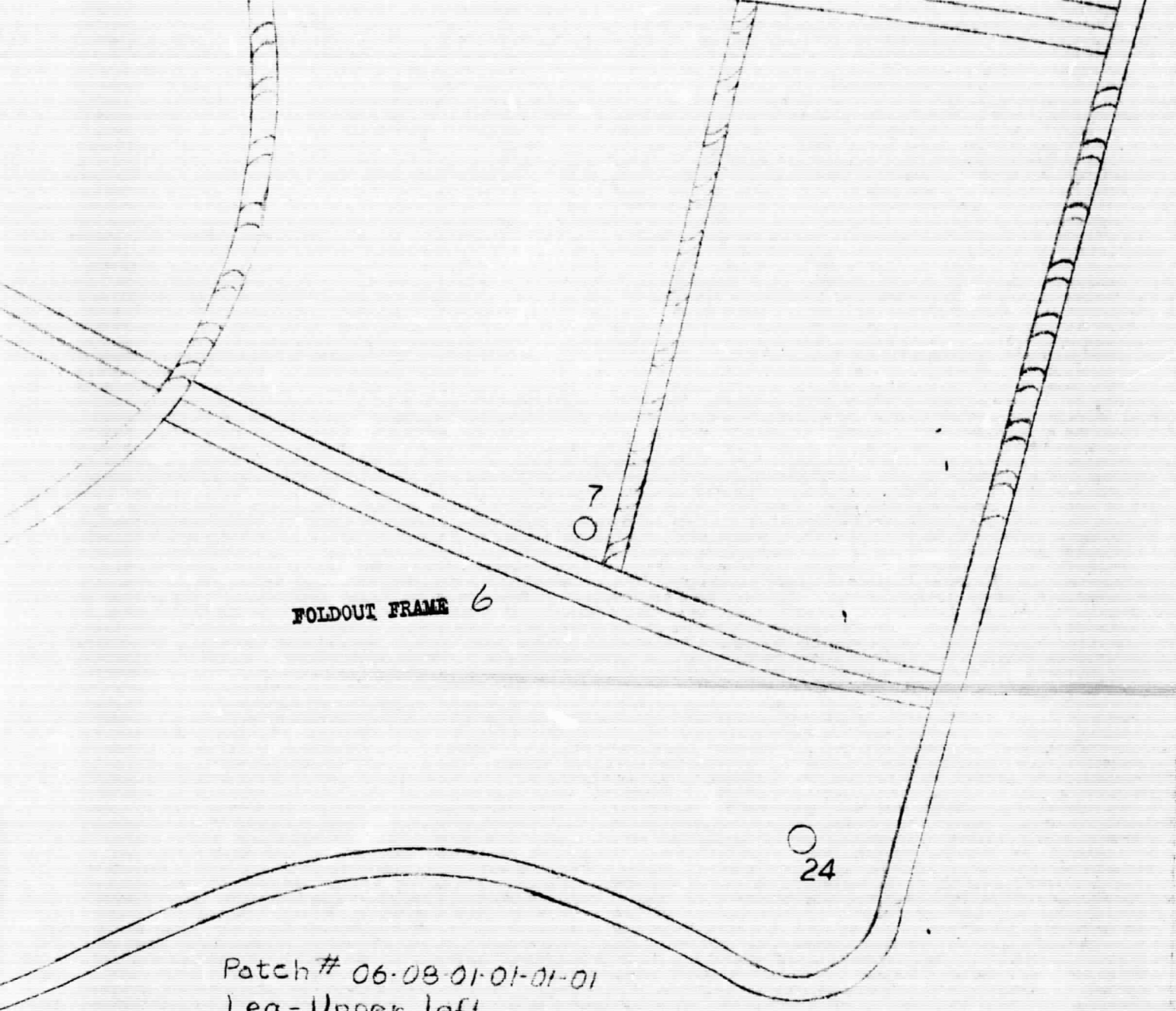


Patch # 06-08-01-01-01-01
Leg - Upper left



FOLDOUT FRAME 7


1
10
FOLDOUT FRAME 5
6
5
4
FOLDOUT FRAME 8



Patch # 06-08-01-01-01-01
Leg - Upper left
10/9/67
Suit #1
Pattern for - Boiler Void 6001-1
Vacuum lines - 1/8" spirap
Pressure lines - 21-22-23-24-25-26
Water lines - 1-2-3-4-5-6-7-8-9-10
Fitting - #2 Van

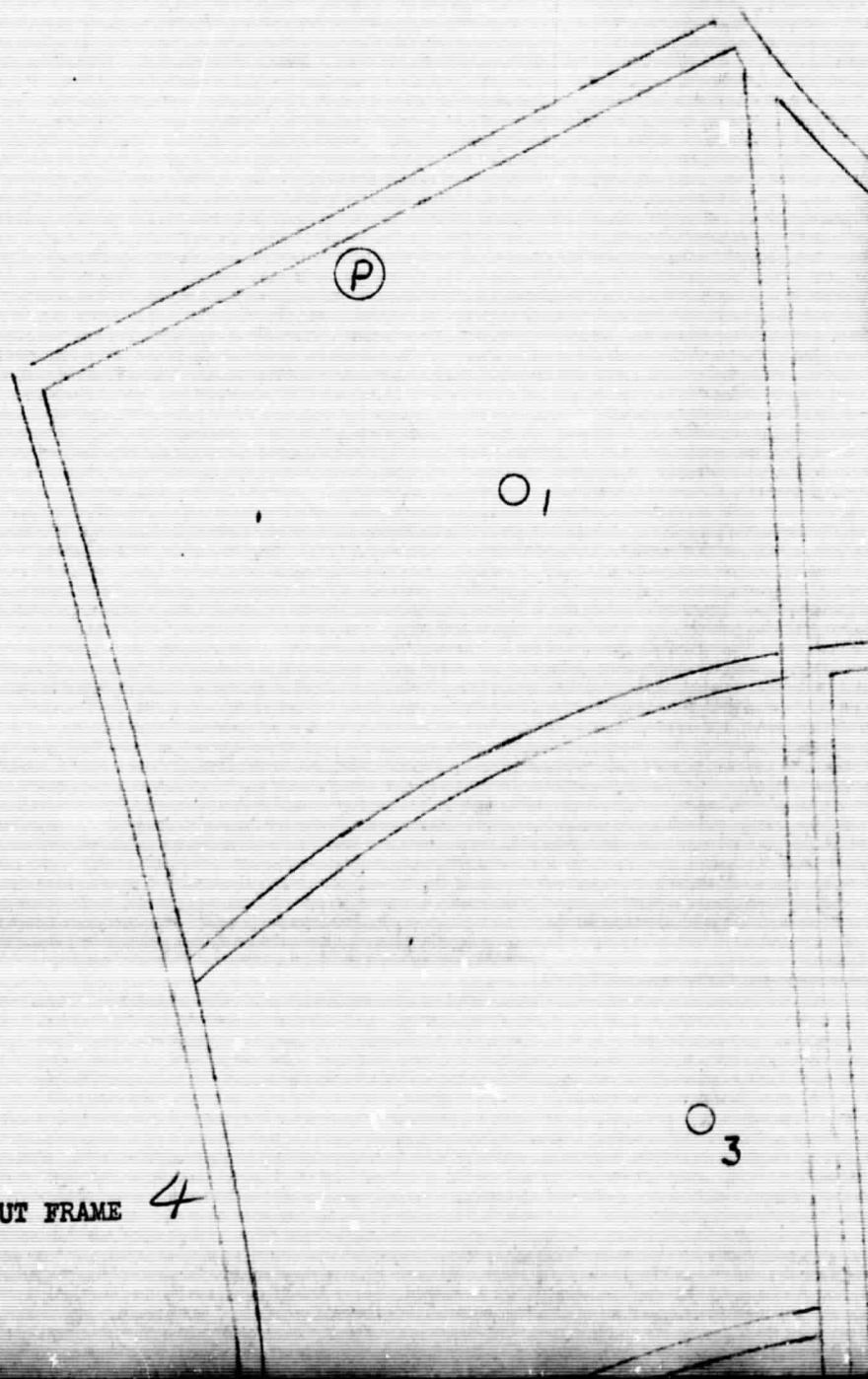
Skin side of patch

RKC

FOLDOUT FRAME 9

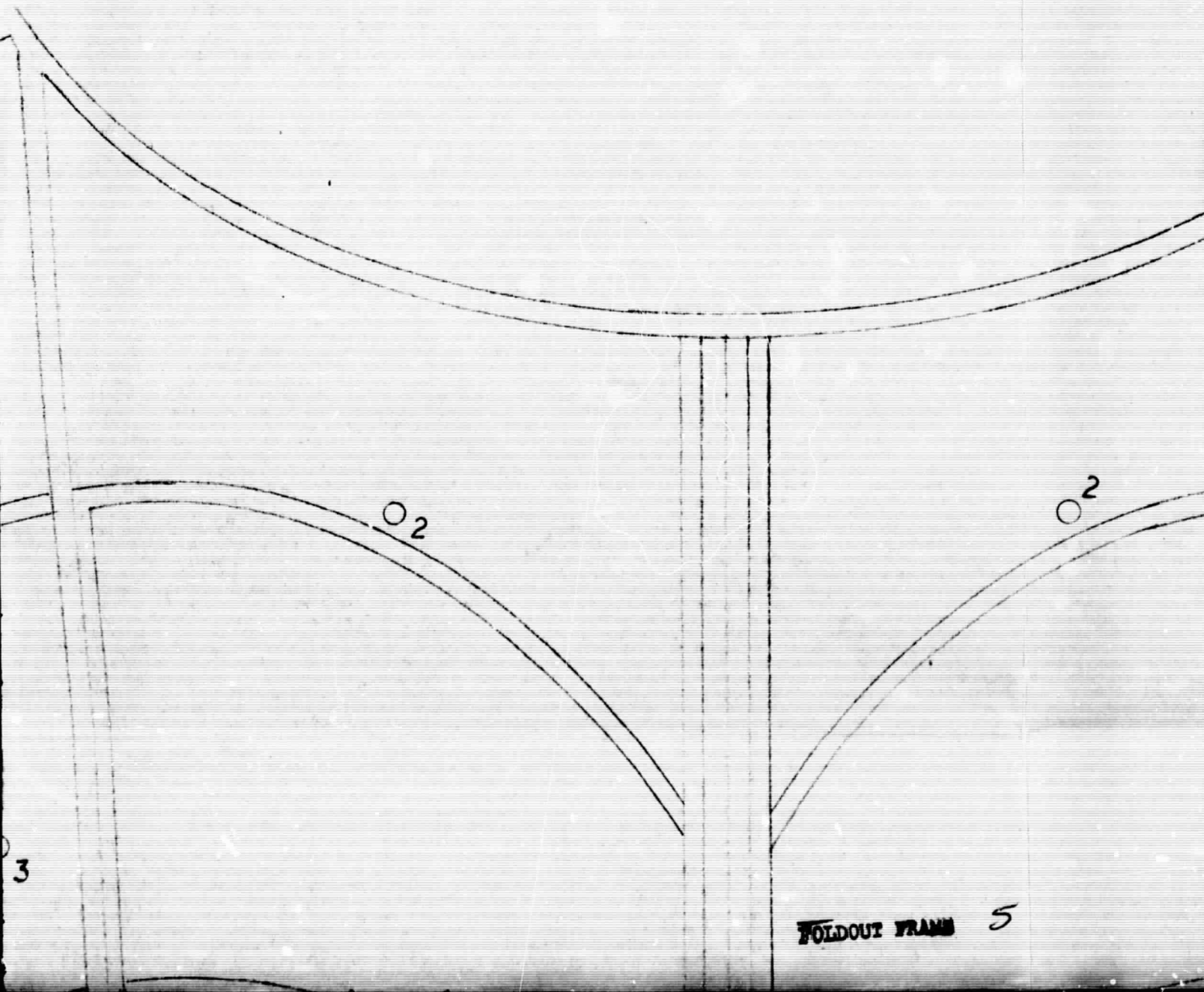
1

FOLDOUT FRAME 1



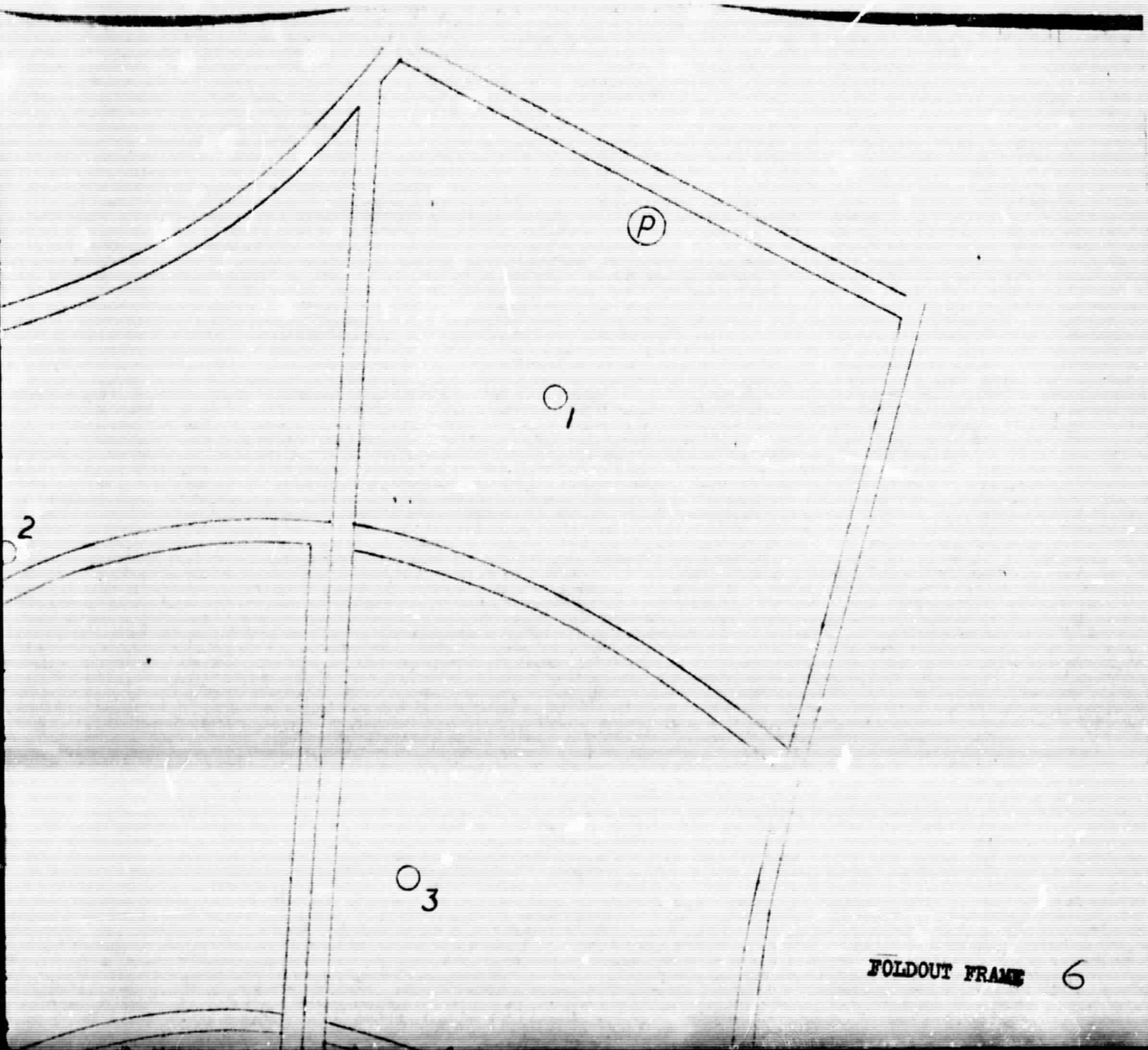
FOLDOUT FRAME 4

FOLDOUT FRAME 2

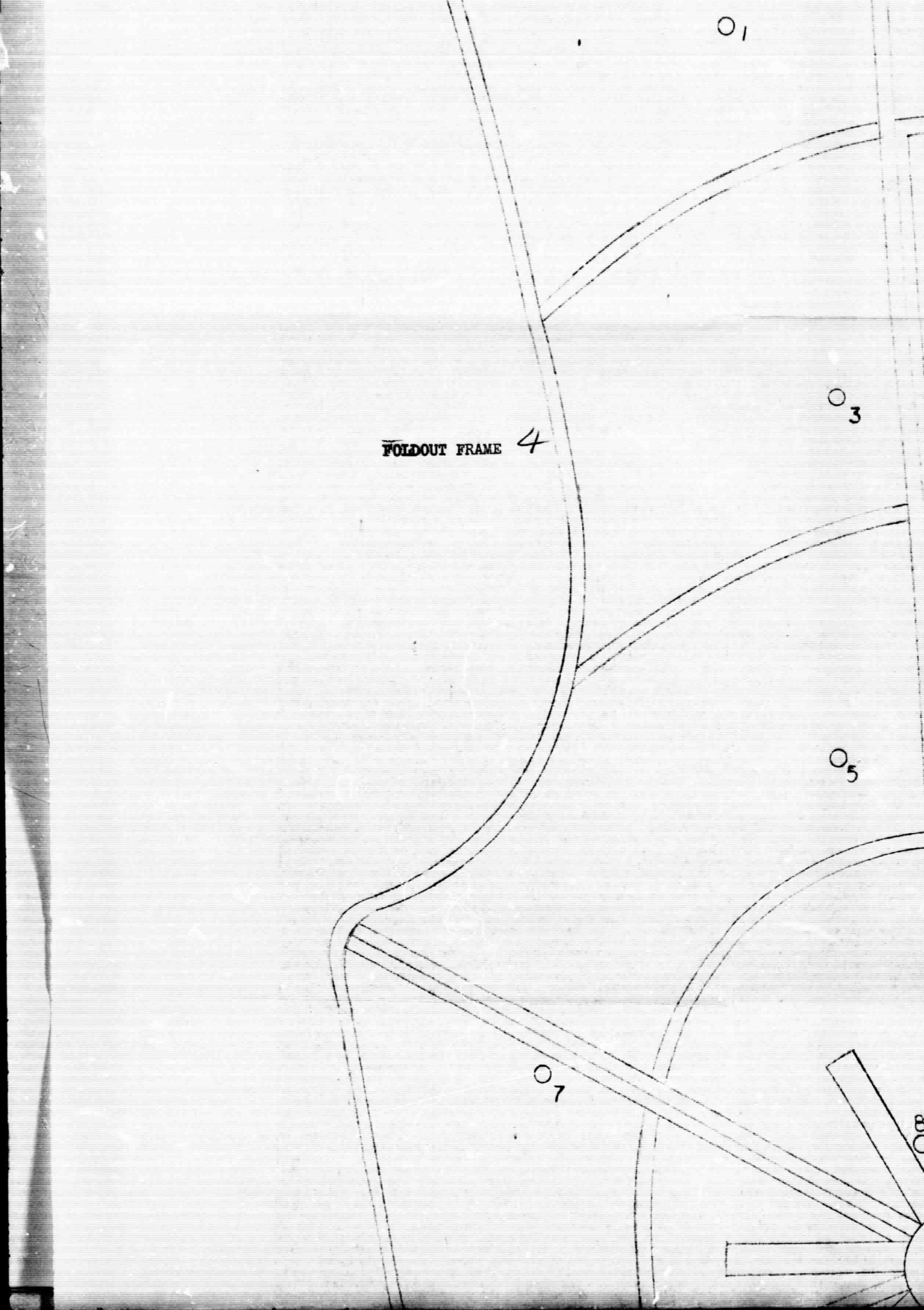


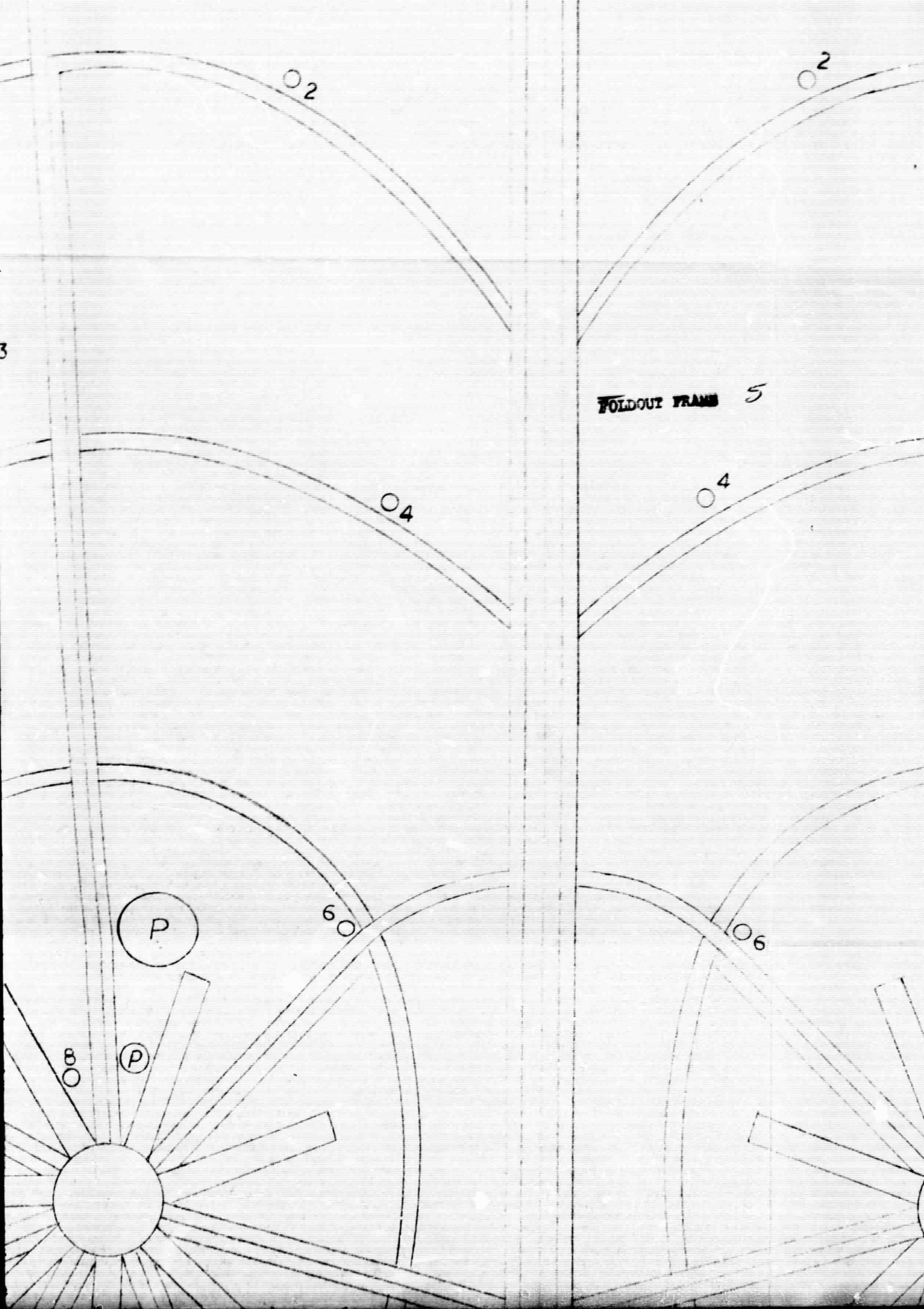
1

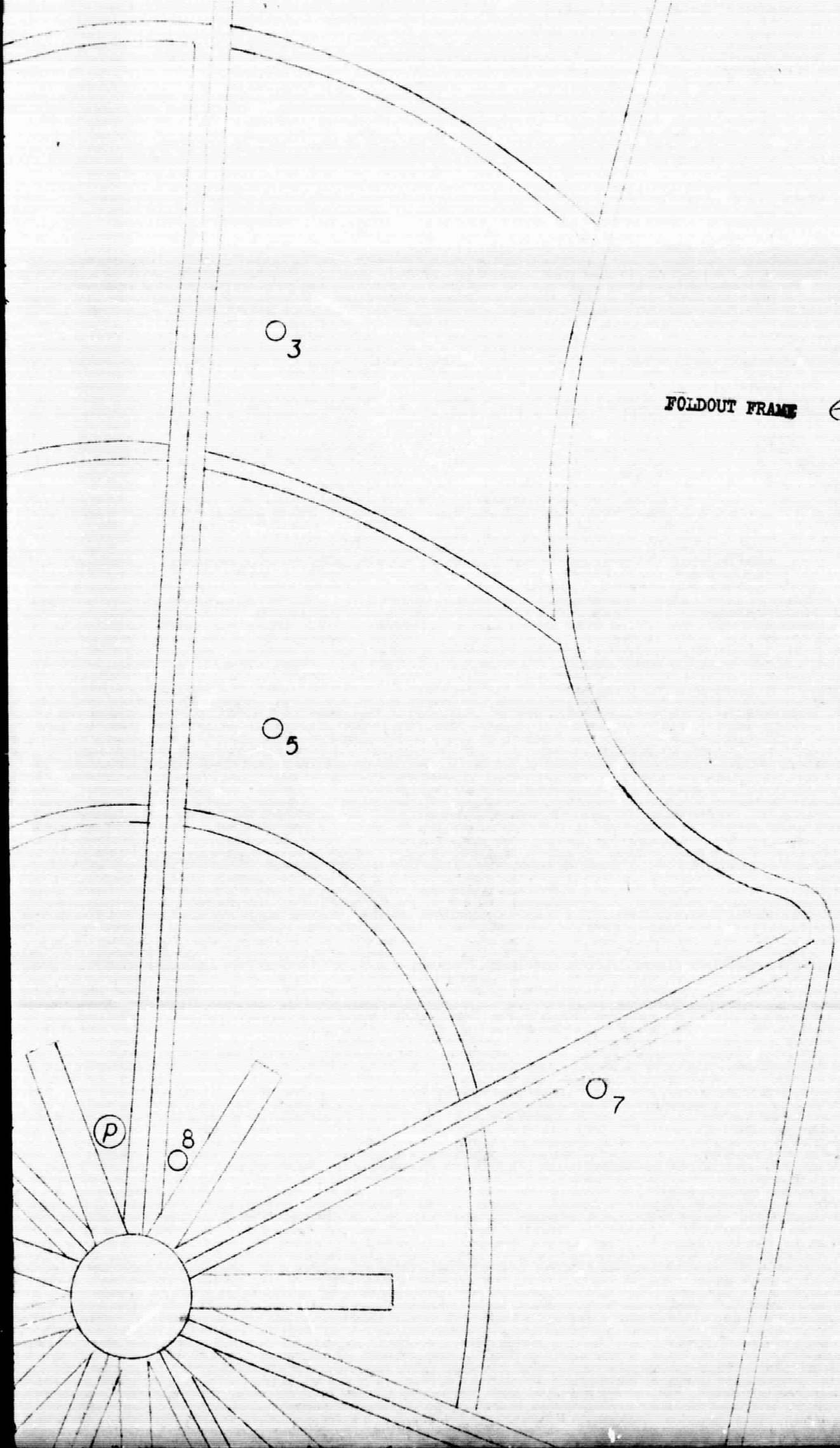
FOLDOUT FRAME 3



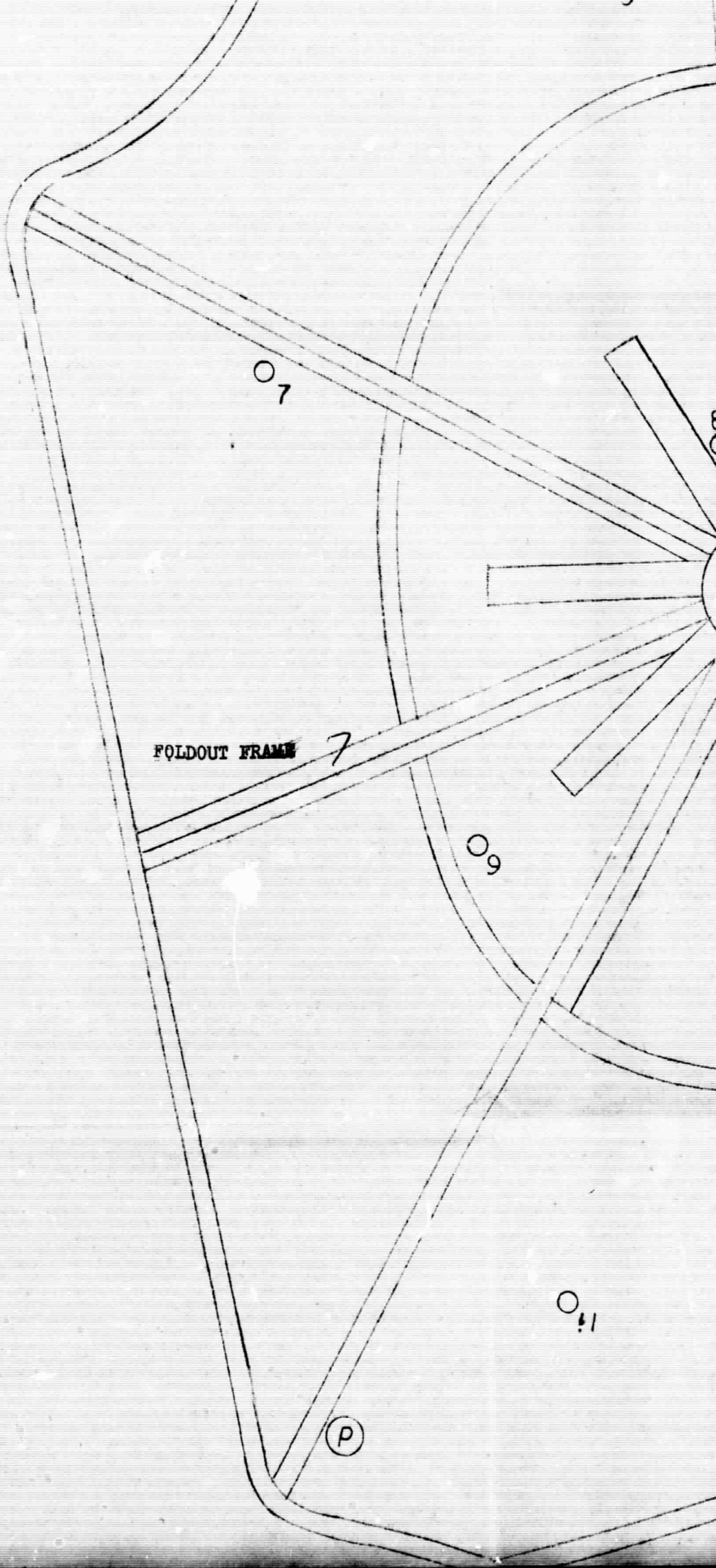
FOLDOUT FRAME 6

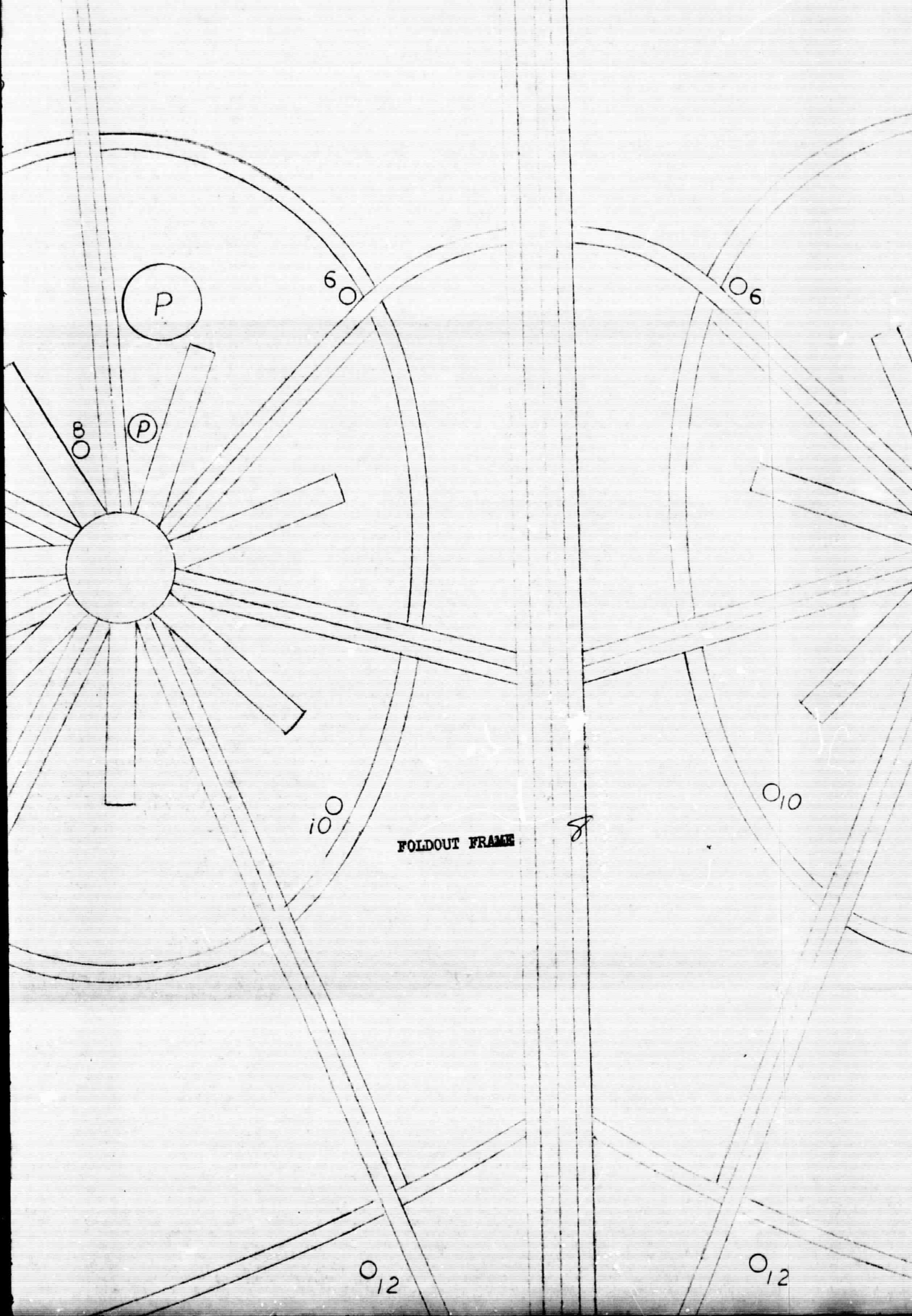

O1
O3
FOLDOUT FRAME 4
O5
O7


2
2
FOLDOUT FRAME 5
4
4
P
6
6
8
P

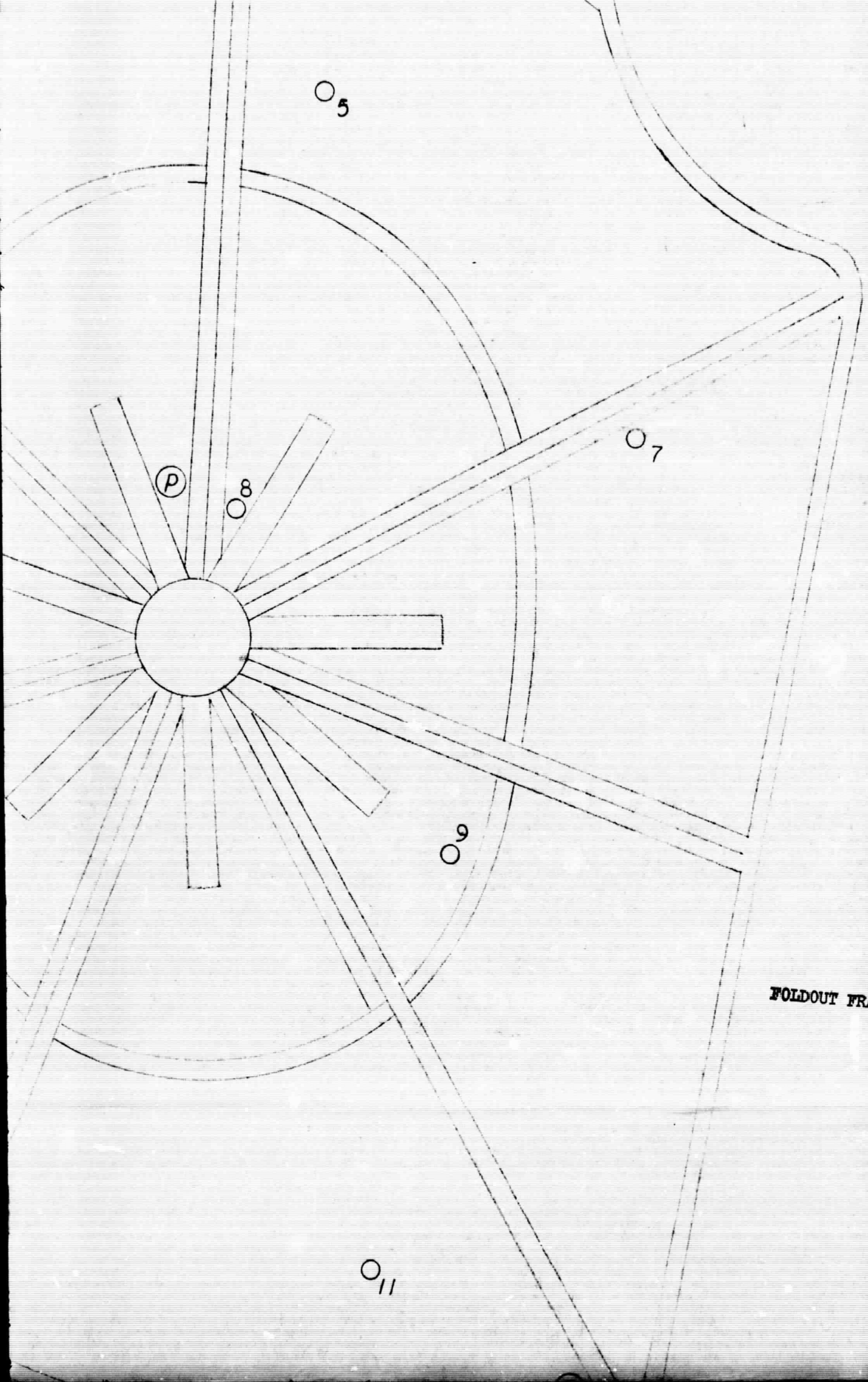


FOLDOUT FRAME 6

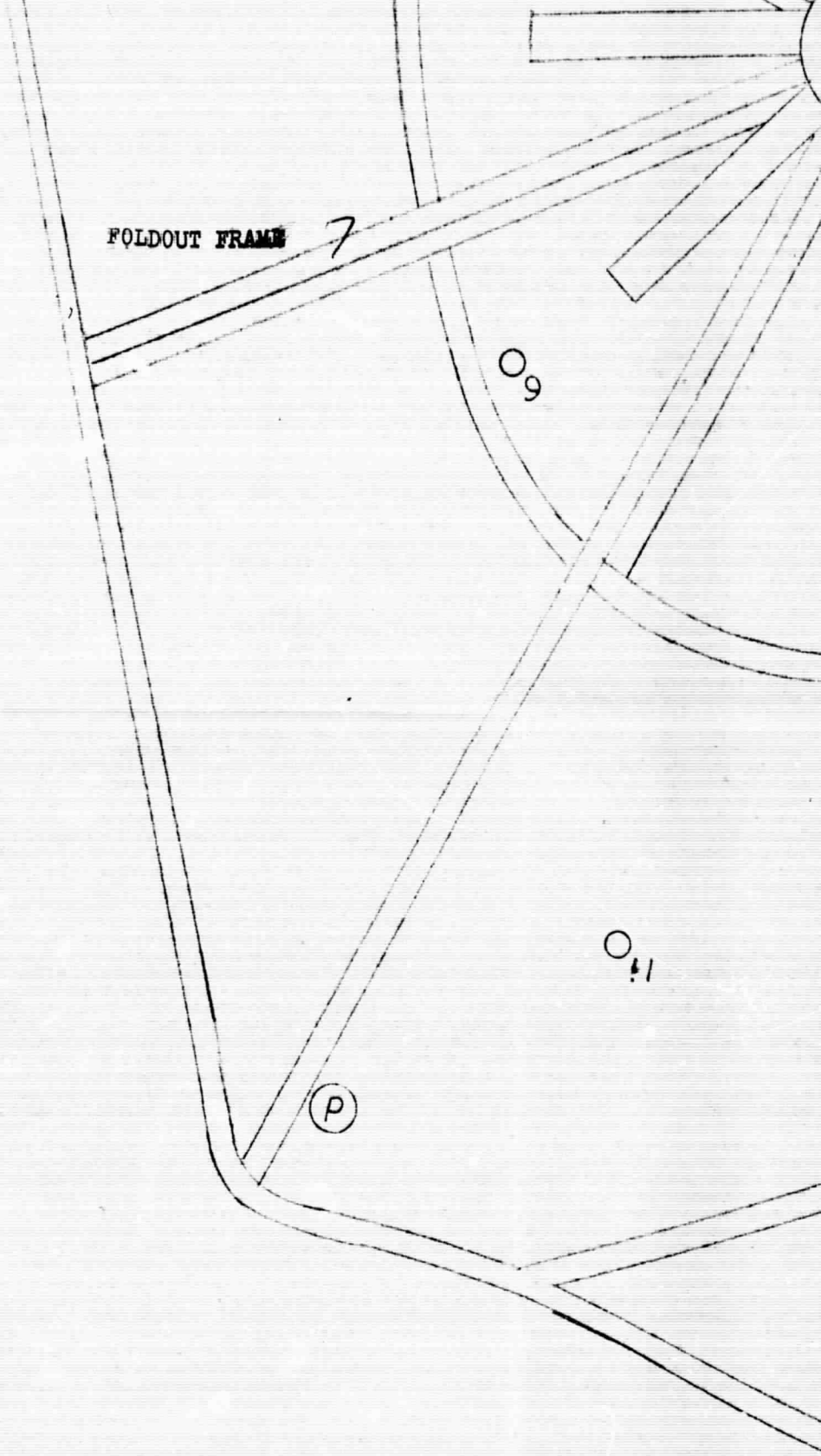

O7
FOLDOUT FRAME 7
O9
O11
P



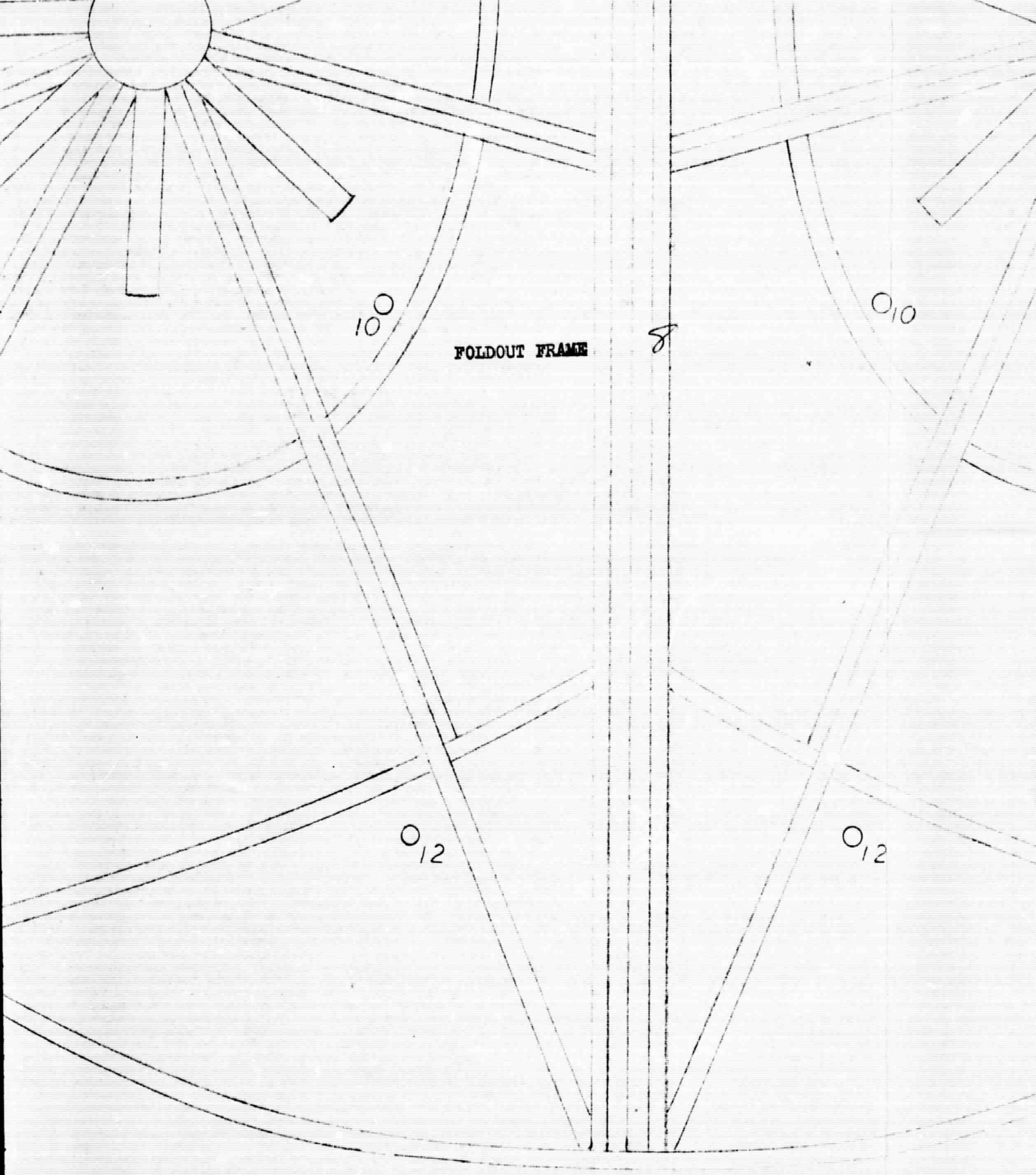
FOLDOUT FRAME 8



FOLDOUT FRAME 9

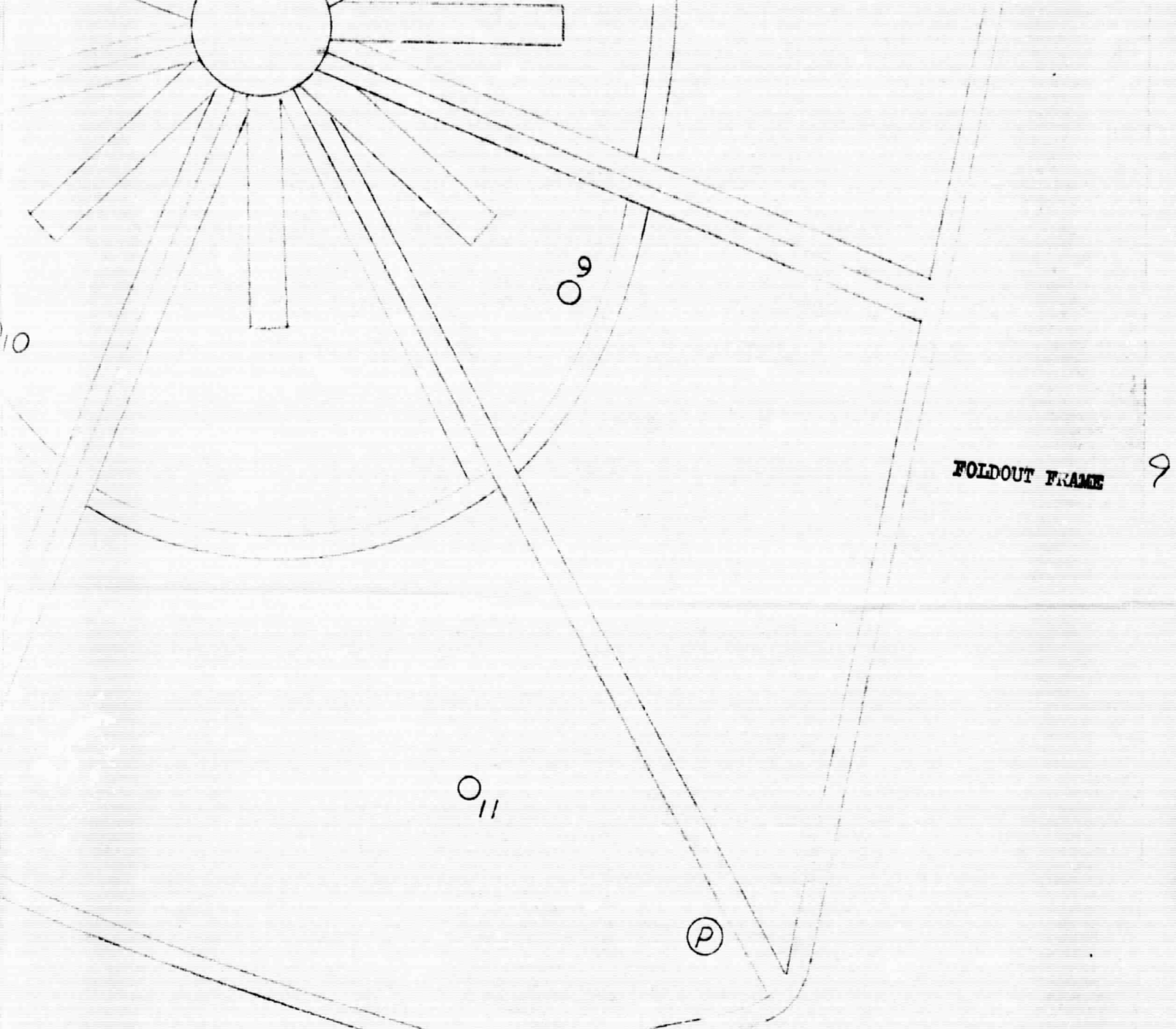


FOLDOUT FRAME 10



FOLDOUT FRAME

FOLDOUT FRAME 11

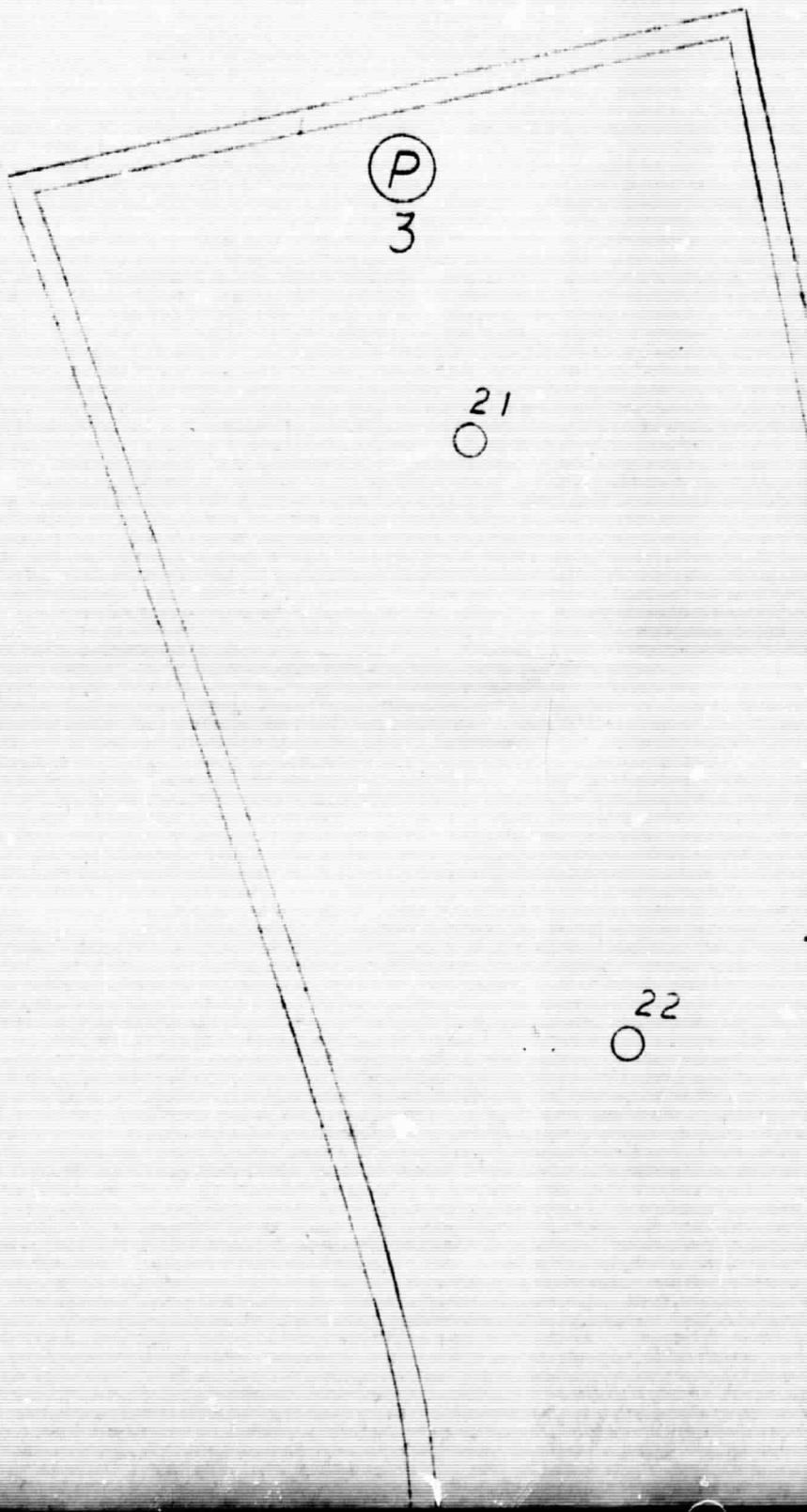


PATCH #13-05h-01-01-01-01
TORSO BACK - outside of patch
12/12/67
PATTERN FOR:
BOILER VOID — 0001-1
VACUUM LINES 1/8" SILICA
WATER LINES - 1 — 12
PRESSURE PICKUPS - (6)

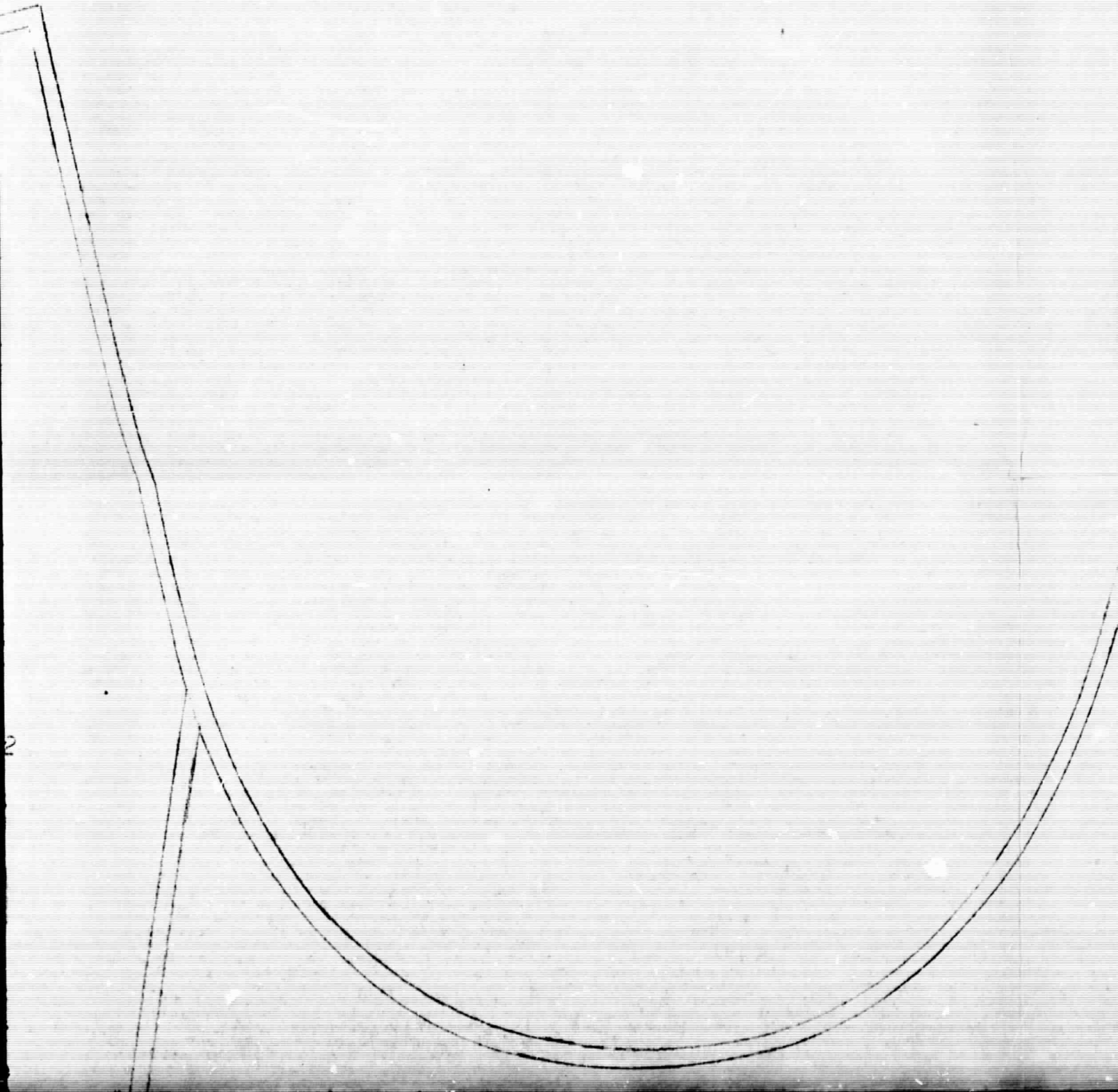
FOLDOUT FRAME 9

FOLDOUT FRAME 12

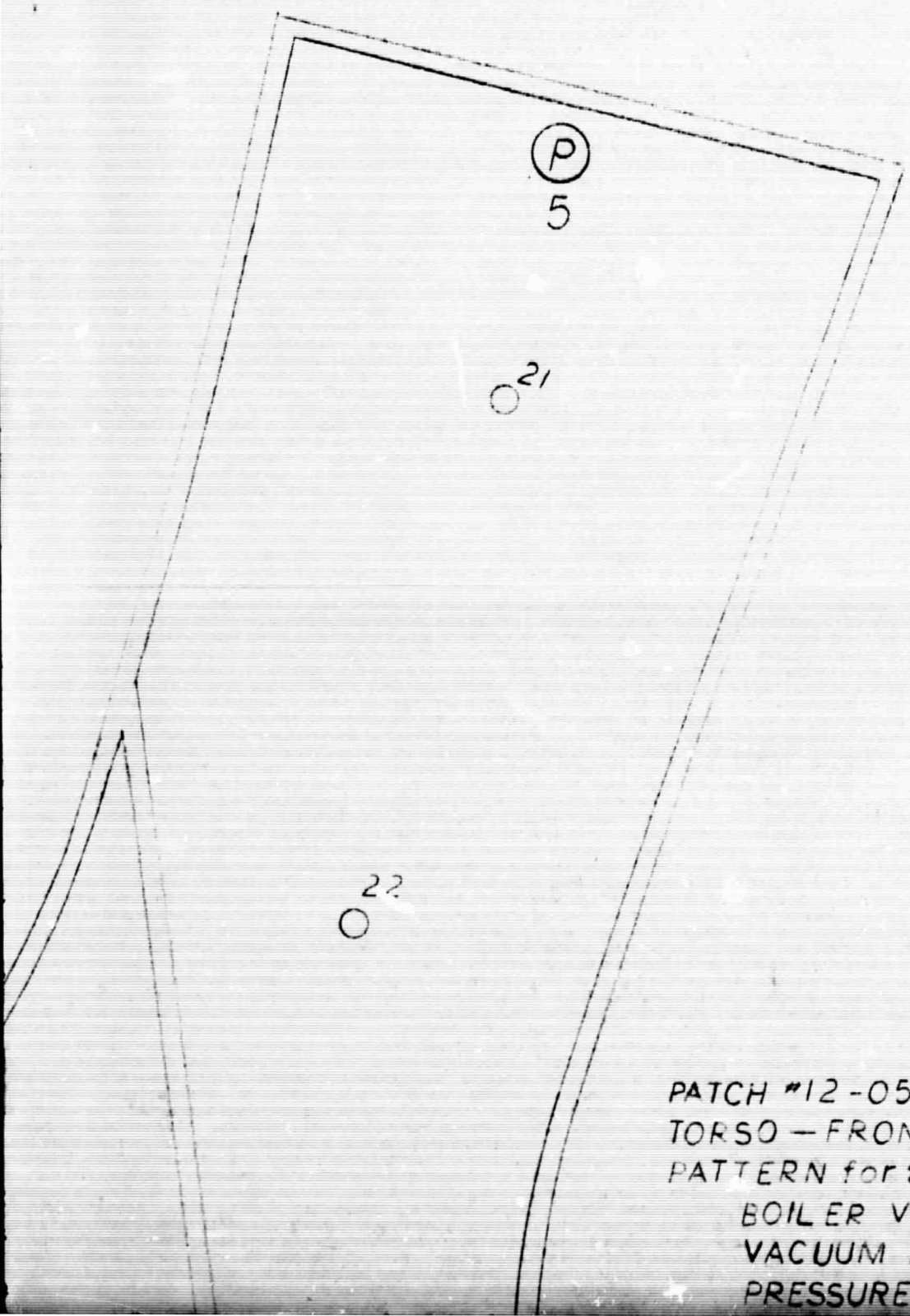
FOLDOUT FRAME 1



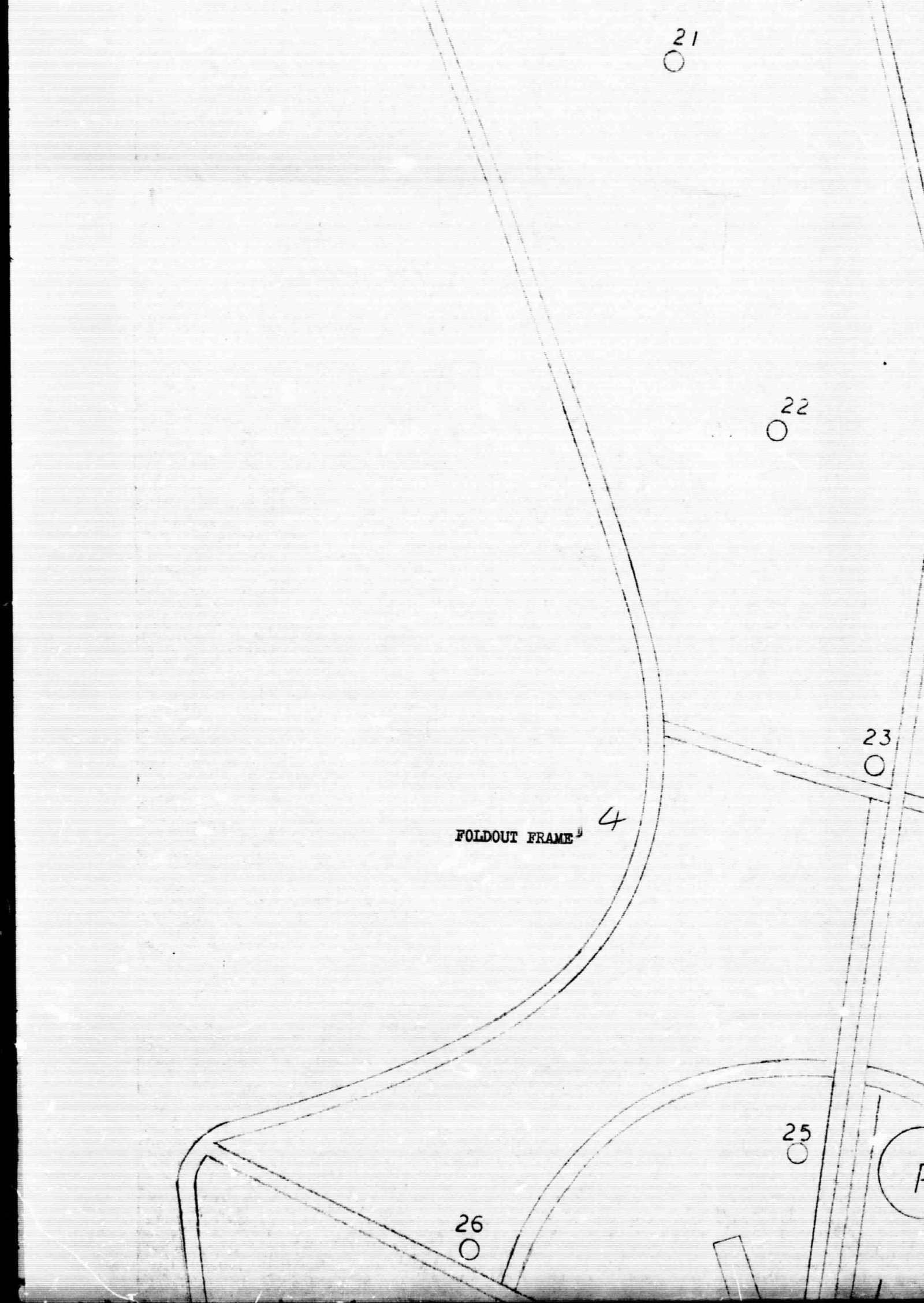
FOLDOUT FRAME 2

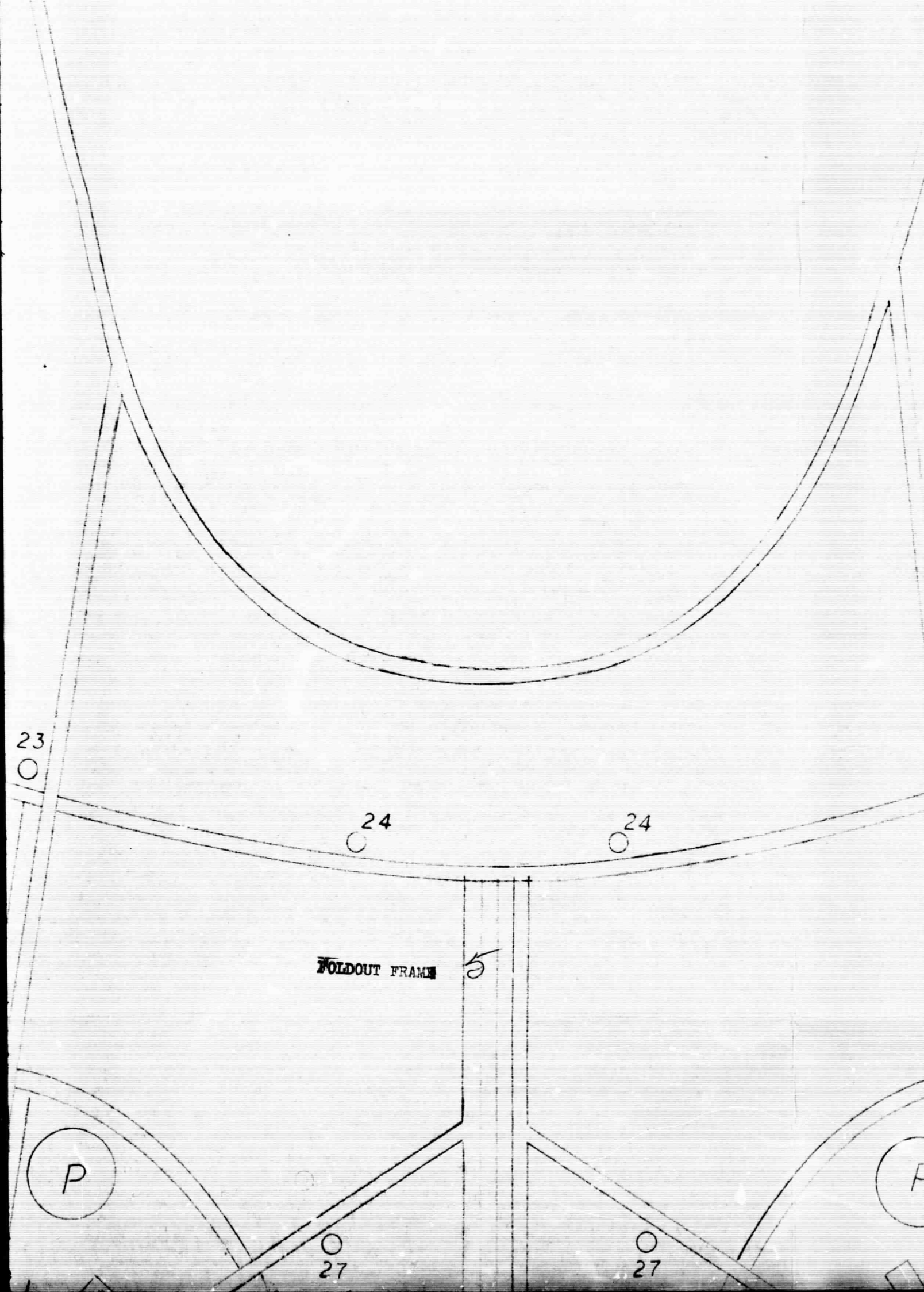


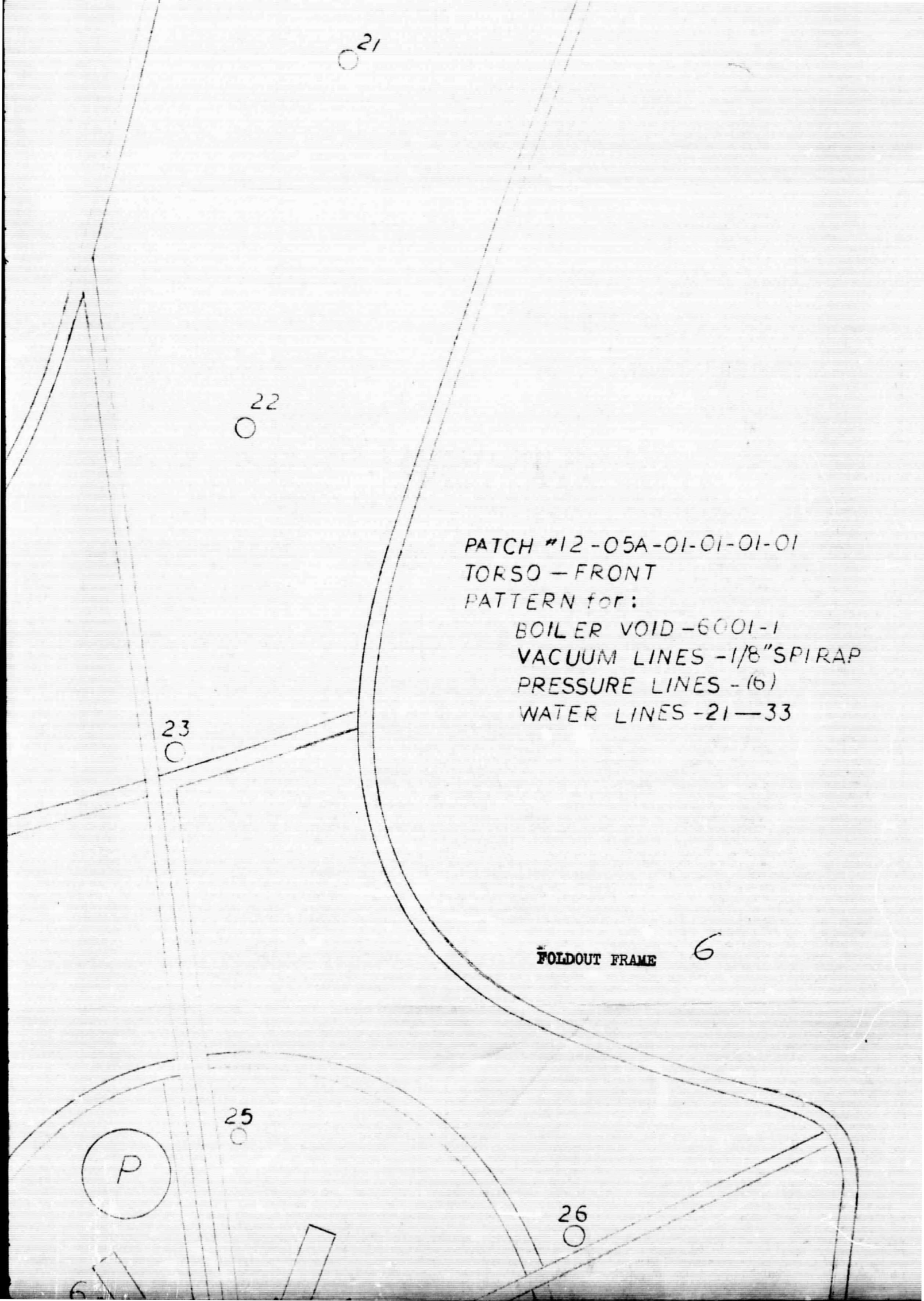
FOLDOUT FRAME 3



PATCH #12-05A-01-01-01-01
TORSO — FRONT
PATTERN for:
BOILER VOID -6001-1
VACUUM LINES -1/8" SPIRAP
PRESSURE LINES - (6)

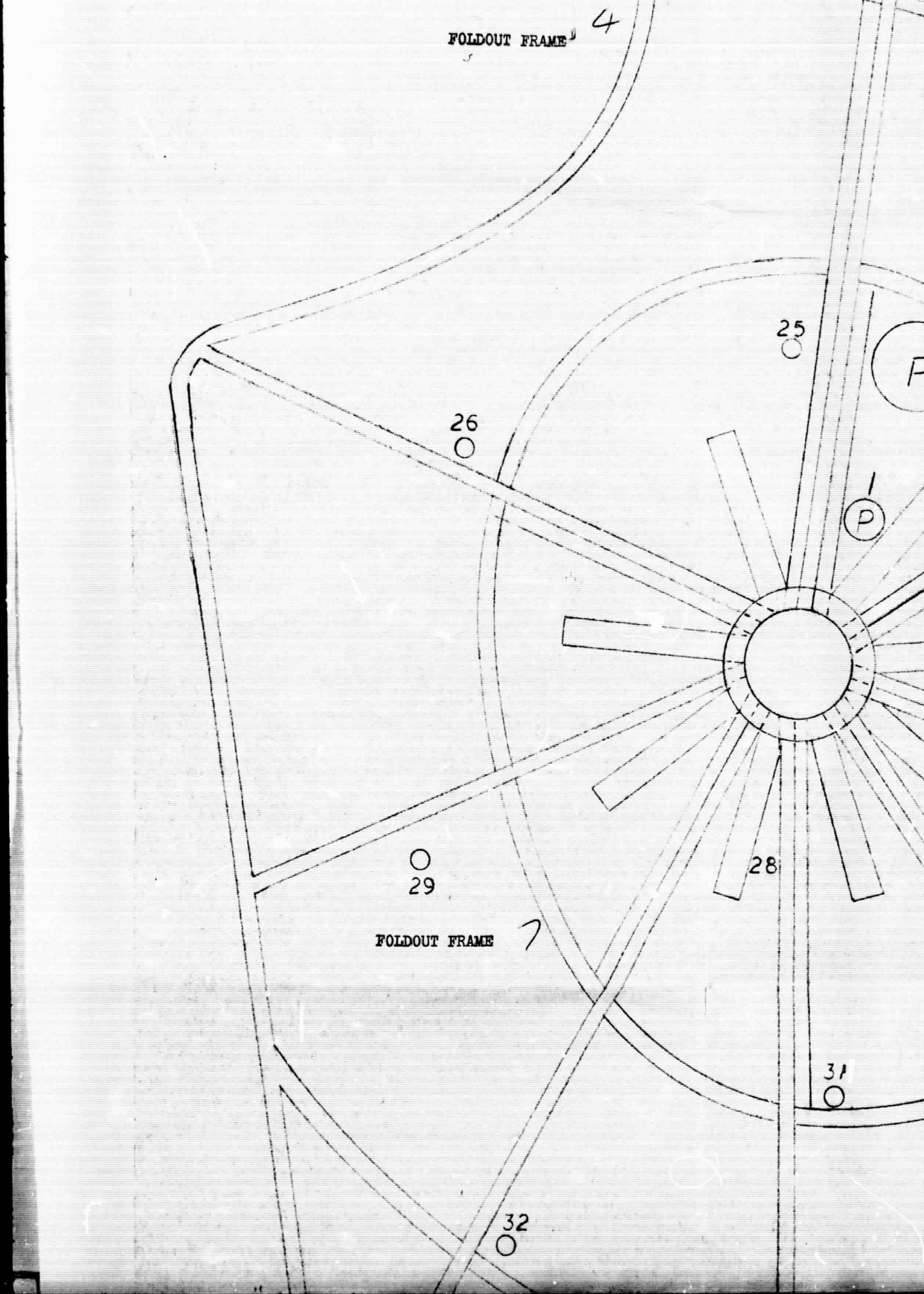

21
22
23
FOLDOUT FRAME 4
25
26

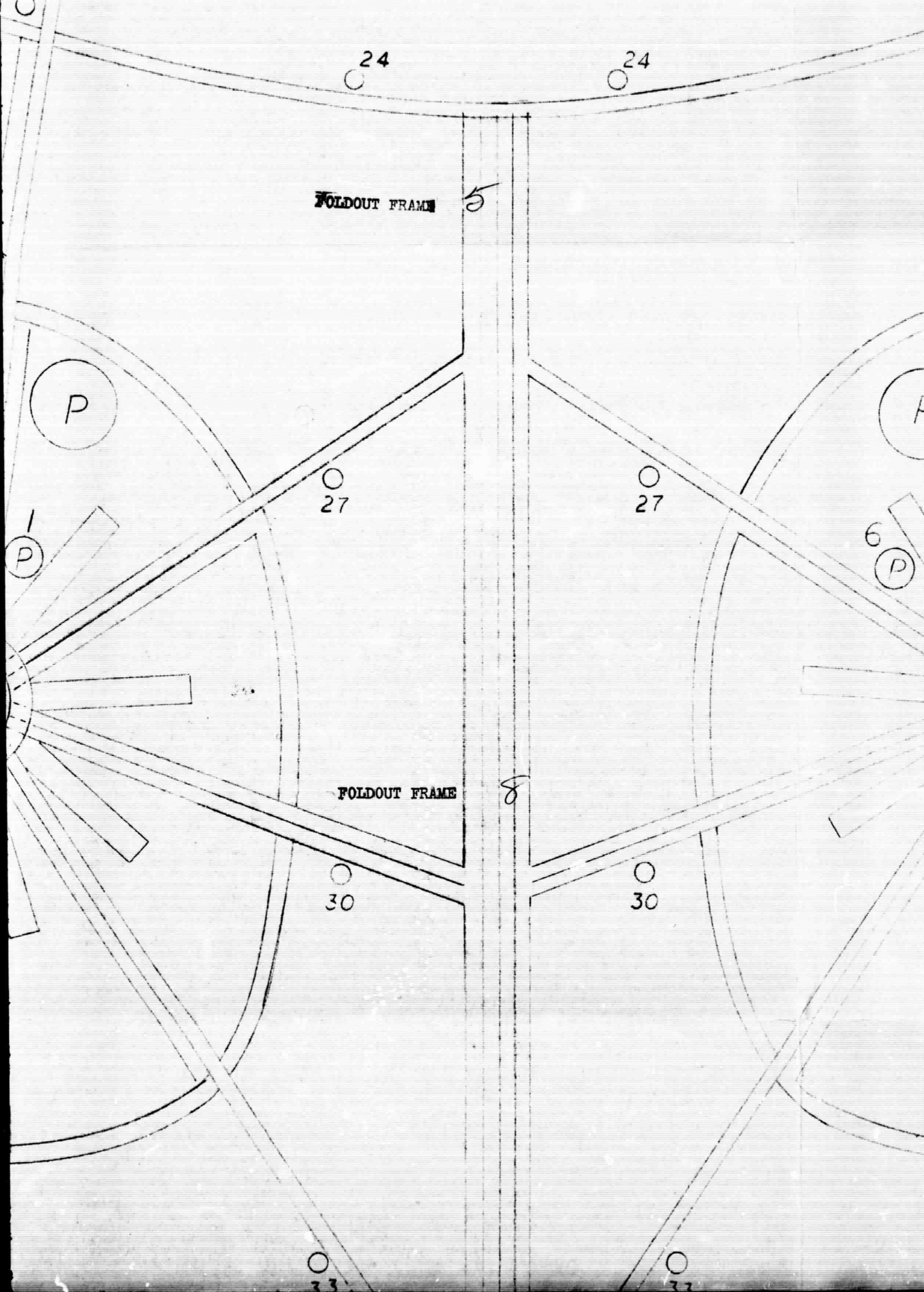

23
24
24
FOLDOUT FRAME
5
P
27
27

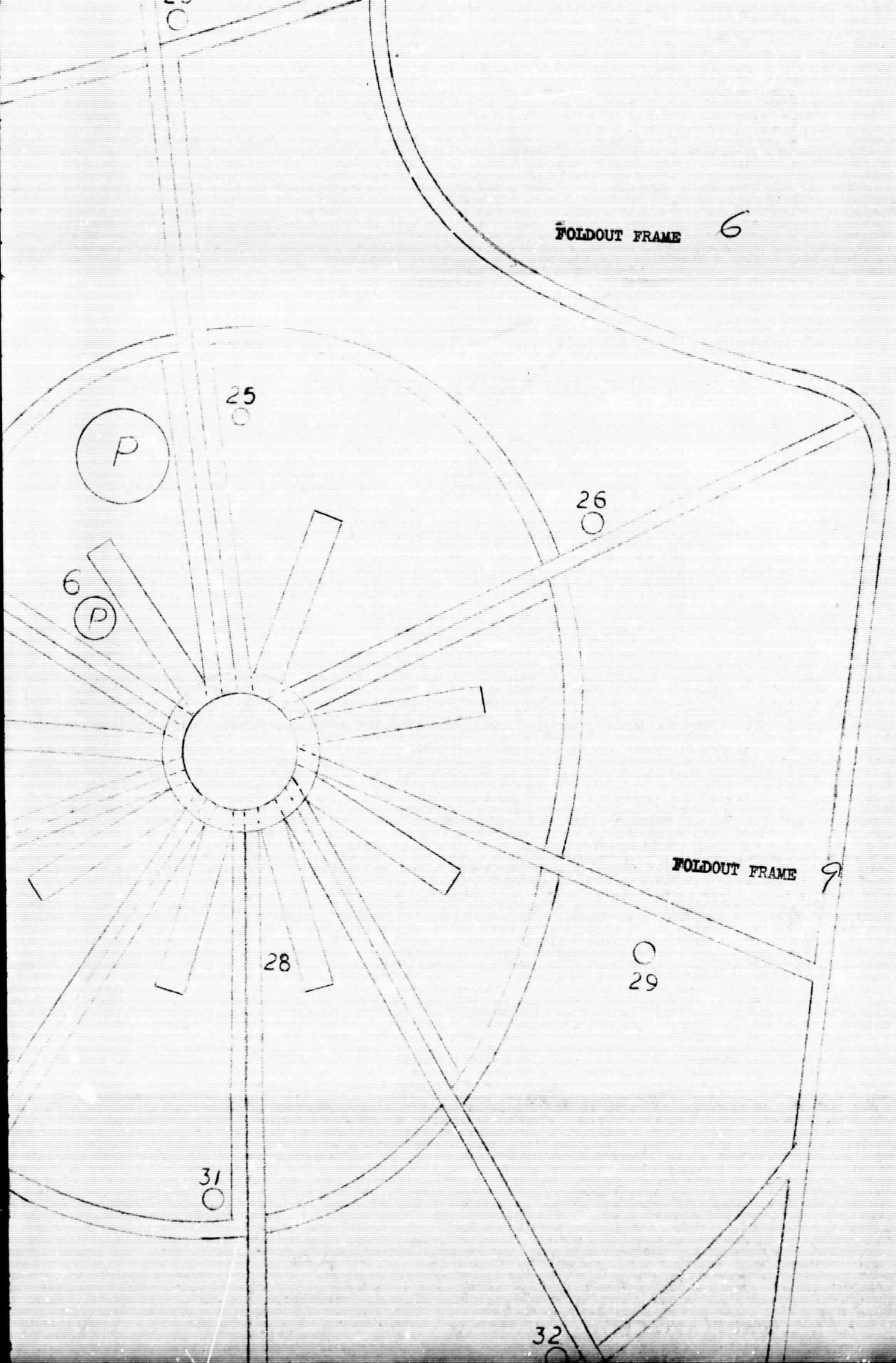


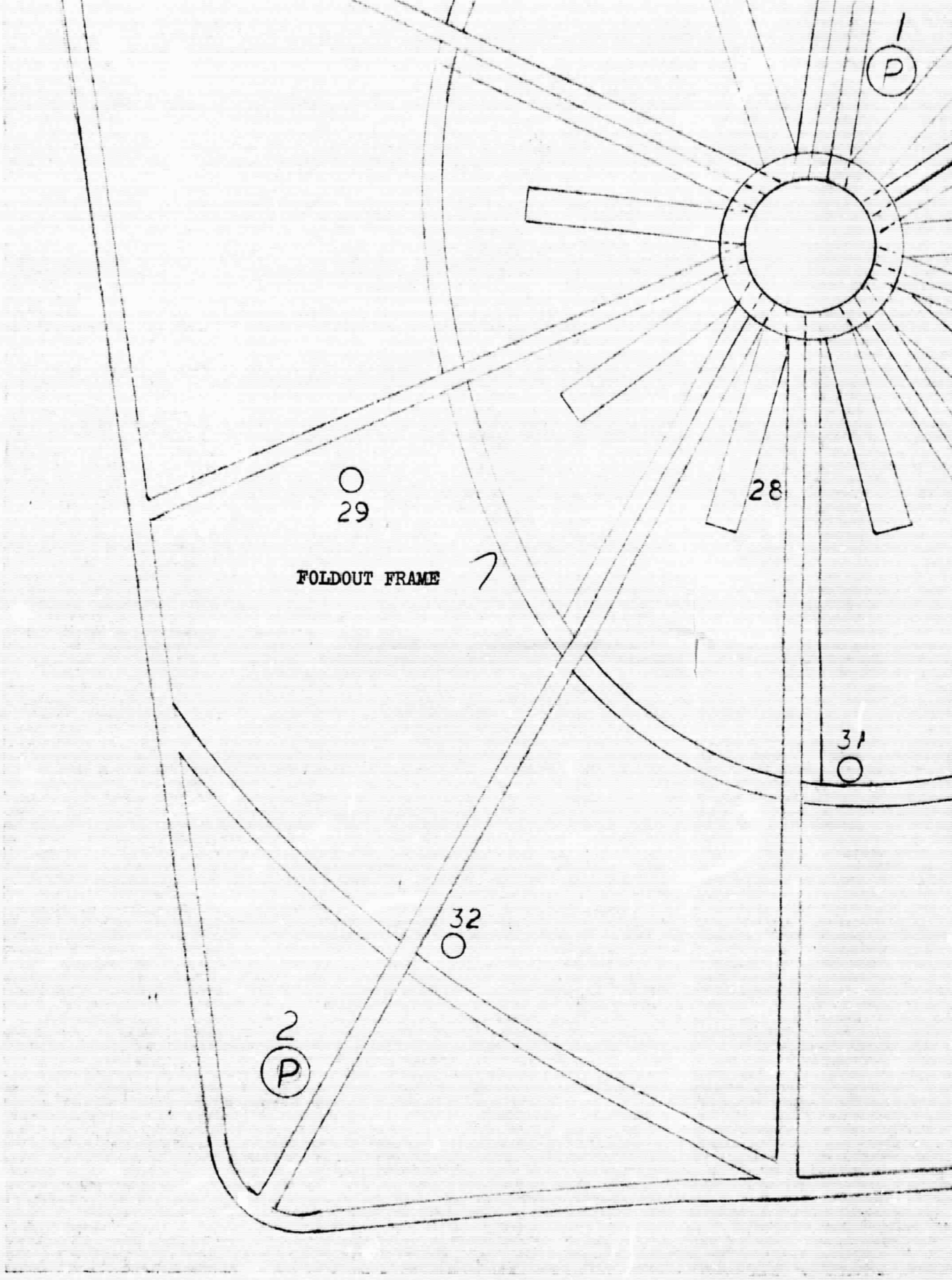
PATCH #12-05A-01-01-01-01
TORSO — FRONT
PATTERN for:
BOILER VOID -6001-1
VACUUM LINES -1/8"SPIRAP
PRESSURE LINES - (6)
WATER LINES -21—33

FOLDOUT FRAME 6


FOLDOUT FRAME
4
25
26
29
28
31
32
FOLDOUT FRAME
7

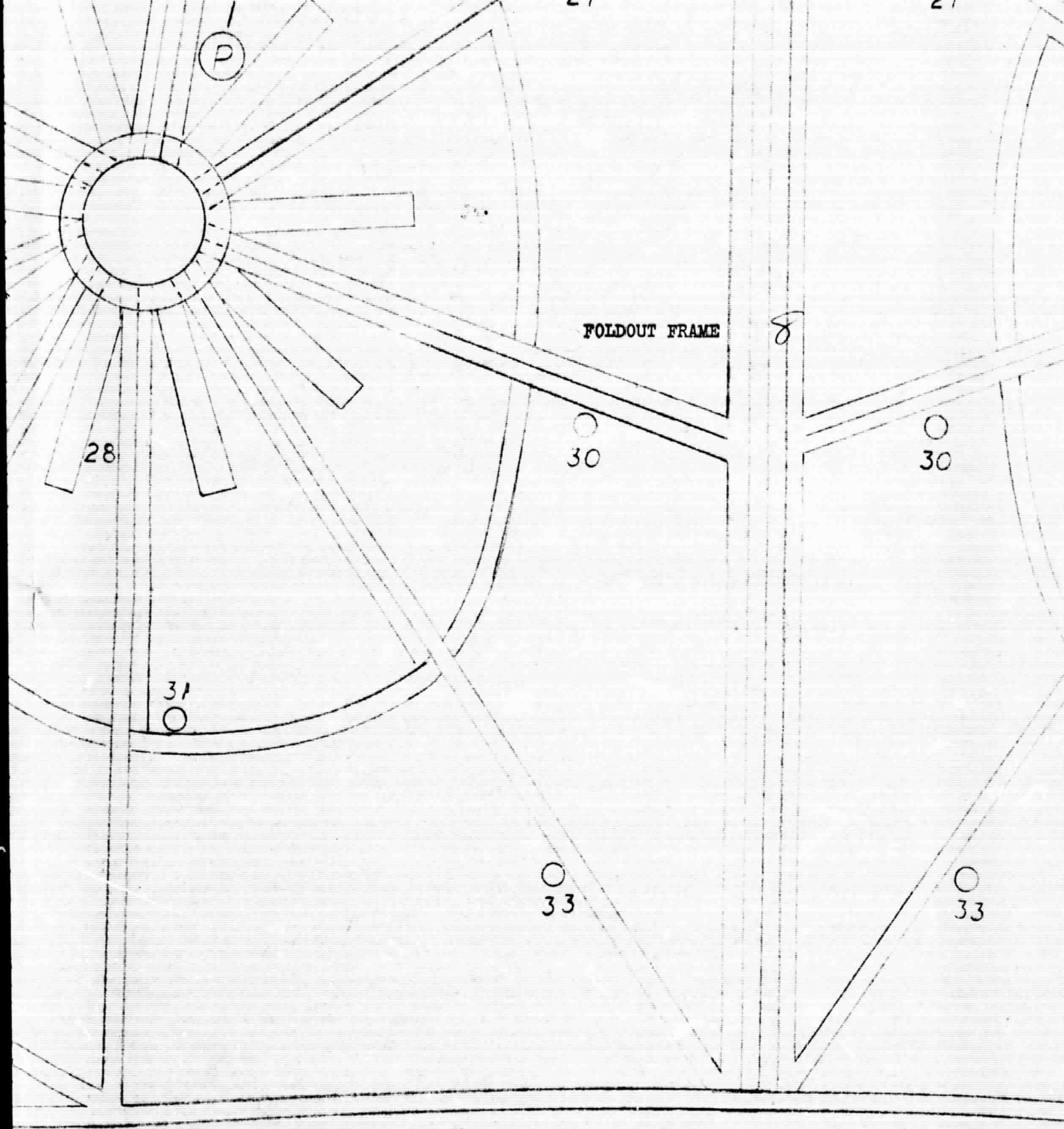

24
24
FOLDOUT FRAME
5
P
27
27
1
P
6
P
FOLDOUT FRAME
8
30
30
33
33

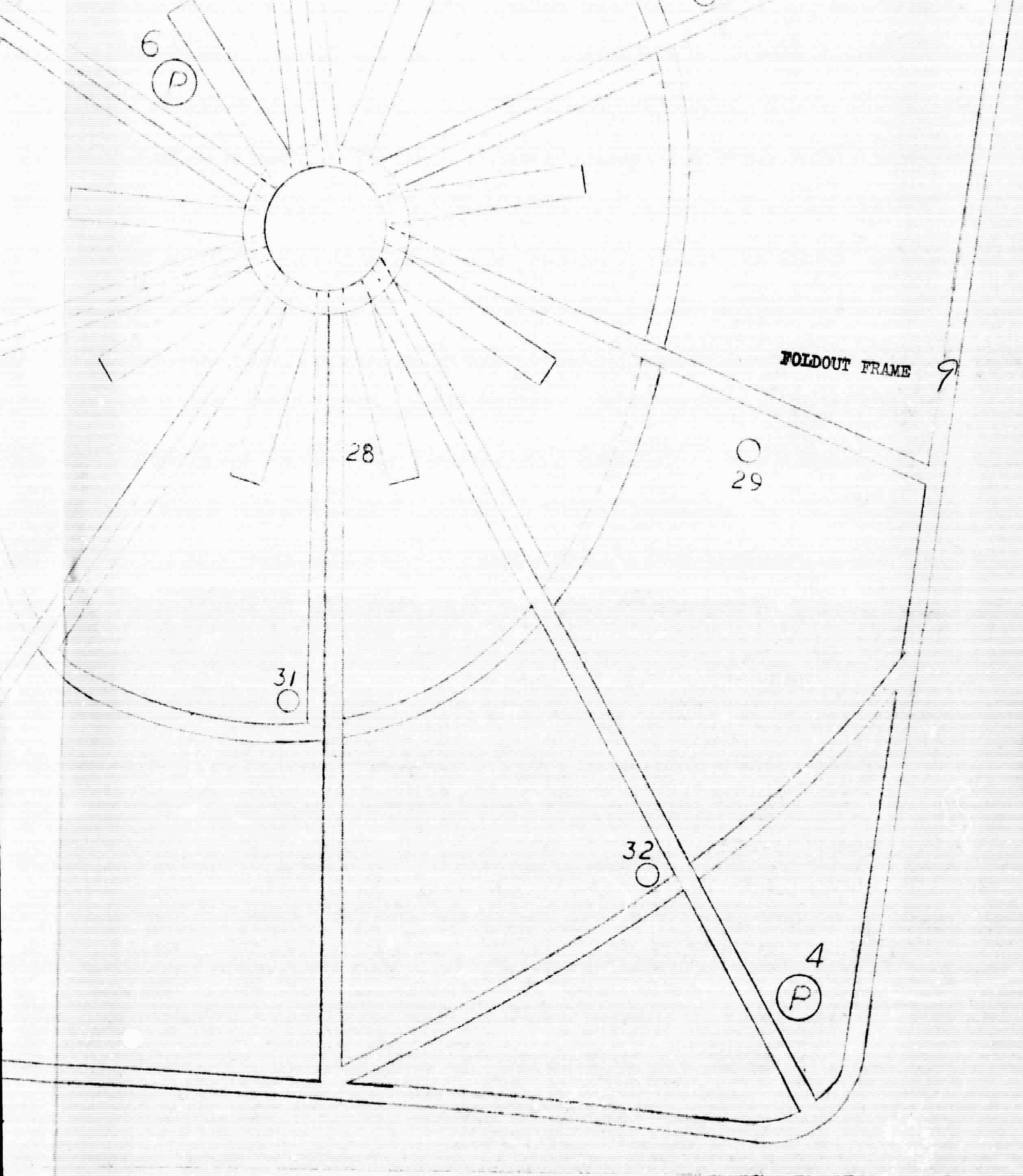

FOLDOUT FRAME 6
25
P
26
6
P
FOLDOUT FRAME 9
28
29
31
32



FOLDOUT FRAME 7

FOLDOUT FRAME 10


P
FOLDOUT FRAME
28
30
30
31
33
33



FOLDOUT FRAME 9

FOLDOUT FRAME 12