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Test Data From The US - Demonstration Poloidal Coil Experiment

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Test Data From The US - Demonstration Poloidal Coil Experiment

by

Superconducting Magnet Development Group
MIT Plasma Fusion Center

and

The Japan Atomic Energy Research Institute

ABSTRACT

The US - Demonstration Poloidal Field Coil (US-DPC) experiment took place successfully at the Japan Atomic Energy Research Institute (JAERI) in late 1990. The 8 MJ niobium-tin coil was leak tight; it performed very well in DC tests; it performed well in AC tests, achieving approximately 70% of its design goal. An unexpected ramp-rate barrier at high currents was identified. The barrier could not be explored in the regime of higher fields and slower ramp rates due to limitations of the background-field coils.

This document presents the results of the experiment with as little editing as possible. The coil, conductor, and operating conditions are given. The intent is to present data in a form that can be used by magnet analysts and designers.

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1. Executive Summary

The United States Demonstration Poloidal Coil (US-DPC) was built and tested under MIT supervision in a collaboration between the Japan Atomic Energy Research Institute (JAERI) and the United States Department of Energy (DOE). The objective of the collaboration was the development of superconducting poloidal coil technology applicable to the next generation of fusion experimental devices. The three goals of the experiment were:

1. Evaluation of the manufacturing process in terms of coil performance. For example, did the coil reach the short sample performance of the wire? Did the high-current lap joints dissipate too much power? Note that fabrication techniques for coils built from the brittle intermetallic compound Nb_3Sn differ significantly from those built of the ductile alloy NbTi or built of ductile copper.

2. AC operation to 10 T at 10 T/s. Was the coil capable of being charged with a trapezoidal waveform from zero current to constant full current at significant magnetic fields?

3. Evaluation of a dual-flow cooling scheme. Is a double-conduit cooling scheme, with independent cable-space and corner helium flows, effective at removing the significant AC-loss heat loads in an ohmic heating coil?

The goals of the US-DPC experiment were only partially realized due to unanticipated AC behavior of the coil. Results are summarized below:

1. Evaluation of the manufacturing process in terms of coil performance. Coil performance in the DC mode was excellent. The coil was leak tight under moderate mechanical loads, the cryogenic system worked properly, lap joint resistances were low, the quench protection system worked well, and mechanical behavior of the coil was reproducible. Cable current-sharing temperatures exceeded short sample predictions by up to $\approx 10\ \%$, implying little or no degradation of the Nb_3Sn superconductor by strain or damage - this is the most significant result of the experiment.

2. AC operation to 10 T at 10 T/s. The design goal of a charge from 0 T to 10 T at 10 T/s was not realized. However, operation from 0 T to 7 T at 7 T/s was achieved. An unanticipated ramp-rate limitation was identified, which appeared to be related to short-duration energy disturbances and the "limiting current" of the conductor and not to AC losses - this is the second significant result of the experiment.

3. Evaluation of a dual-flow cooling scheme. Systematic evaluation of the dual-flow cooling scheme was abandoned when the ramp-rate limitation was identified. Heat removal by corner flow typically equaled or exceeded heat removal by cable-space flow.

To itemize manufacturing aspects relevant to the envisioned International Thermonuclear Experimental Reactor (ITER), the US-DPC contributed to high-field, large-coil technology through development of:

- loss-optimized, internal-tin Nb_3Sn wire,
- chrome plating for Nb_3Sn wire,
- Incoloy 908, a low-COE-superalloy conduit,
- wind-and-react techniques on a 2-m-diameter scale,
- a vacuum furnace on a 3-m-diameter scale, and
- low-loss, high-current, Nb_3Sn lap joints.

The experimental results offer several implications for the ITER model coil program. These are:

- Loss optimization of Nb_3Sn wire is effective, since hysteresis losses of the cable were comparable to those predicted from single-wire short samples (see Fig. 9.22).

- Chrome plating is effective as an anti-sintering agent during heat treatment, since cable coupling time constants were comparable to those of single wires (see Table 9.3).

- Vacuum heat treatment is effective in preventing stress-accelerated grain boundary oxidation (SAGBO) of the Incoloy 908 conduit, since the coil was helium-leak tight through more than 300 test cycles.

- Use of a low COE conduit and a wind-and-react technique appear to be sufficient to optimize the critical properties of Nb_3Sn (see Fig. 7.7).

- High-current, low-resistance Nb_3Sn lap joints can be built successfully in an industrial environment (see Section 11).

- No ramp-rate limitations appear to exist below a characteristic limiting current defined as the copper-stabilizer current at which Joule heating equals cooling by the surrounding helium (see Fig. 10.5).

2. Introduction

The United States Demonstration Poloidal Coil (US-DPC) was built and tested under the auspices of "Annex V" to the Implementing Arrangement between the Japan Atomic Energy Research Institute (JAERI) and the United States Department of Energy. As stated in the arrangement, the objective of the collaboration was to conduct tests and to evaluate conductor design concepts and performance in support of the development of superconducting poloidal coil technology applicable to the next generation of fusion experimental devices.

3. Purpose

The purpose of this document is to present data from the US-DPC experiment that can be used to estimate the performance of future poloidal coil designs. Emphasis is on the evaluation of AC losses in the US-DPC cable-in-conduit conductor (CICC).

4. Summary of experiment

The experiment began on November 5 and ended on December 20, 1990. The three goals were: (1) evaluation of the manufacturing process in terms of performance; (2) AC operation to 10 T at 10 T/s; and (3) evaluation of a dual-flow cooling scheme (independent control of cable-space and corner flows).

4.1 Statistics

There were two cooldowns of the facility, of duration approximately one week each. A total of 305 runs were done: 73 DC and 232 AC. The US-DPC quenched 51 times; adequate protection was provided by dump signals from both bridge and inlet-mass-flow-meter circuits. The protection system worked well in both the DC and AC modes, although allowance had to be made for the ferromagnetic nature of the Incoloy 908 conduit.

The nominal operating condition was supercritical helium at 4.5 K, 6 atm, and 60 g/s at the inlet; the two lap joints between double pancakes were cooled with liquid rather than supercritical helium, a design decision that proved to be a problem area. The minimum test temperature was 4 K; the maximum 14.8 K. The minimum flow was 15 g/s, or 2.5 g/s per pancake; the maximum was 60 g/s or 10 g/s per pancake.

4.2 Single-coil DC tests

"Single coil" means that the US-DPC was tested alone (zero background field). These tests established that the coil was leak tight, the cooling system was working, the lap joint resistance was low, and the protection system was working. It was concluded that the fundamentals of the coil fabrication were in order.

When the coil reached 100% charge (30 kA) for the first time, a power supply overheat initiated an unplanned dump that yielded a first estimate of AC losses. The losses were approximately 0.1% of the stored energy of 8.2 MJ. They appeared to be within a factor of 2 of estimates made from single-wire measurements at MIT.

To determine if the conductor had significant resistive portions, flow conditions were varied. Most significantly, flow in the cable space was stopped while maintaining corner flow only; the coil was then charged to 30 kA (5.7 T) with no evidence of transition from the superconducting to the normal state.

Current-sharing temperature measurements were made to 30 kA, to compare the 225-strand cabled superconductor to single-wire measurements. These measurements were performed by charging the coil to a given current and then slowly raising the inlet helium temperature above 4.5 K until resistive voltage was seen. It was found that the performance was slightly better than predictions taken from a combination of published literature and single-wire measurements at MIT and the University of Wisconsin, indicating no degradation due to damage or strain of the superconductor. These results were confirmed with critical current tests, in which the inlet helium temperature was raised and stabilized and then the coil charged until resistive voltage was seen.

Intermediate ramp-rate tests were done to see if the US-DPC suffered from the limitations of the Japanese U1 and U2, that is, quenches at ramp rates on the order of minutes. The fastest charge was 30 kA/min (0.1 T/s); no evidence of transition from the superconducting to the normal state was found, indicating no limitation at these ramp times.

Nuclear heating tests were performed using a heater in the cable of double pancake B; the maximum heat load was 200 W at 30 kA. This established that the cooling capacity exceeded the ITER specification. It was observed that flow choking occurred in double pancake B, with the general significance that parallel passages may choke when nuclear heating takes place. (This may be true whether heating is balanced or unbalanced, and can have significance for large ITER-scale magnets.)

In summary, the single-coil DC tests provided a manufacturing evaluation of the coil at low fields. The test results indicated that the coil worked well and was neither significantly damaged nor strained.

4.3 Series-coil DC tests (US+U1+U2)

The US-DPC was charged in series with the U1 and U2 background coils to a peak field of 8 T (25.9 kA). The charging time to 8 T was approximately 14 hours, showing the extreme sensitivity of the U1 and U2 coils to intermediate ramps. The series DC test verified the integrity of the US-DPC to 80% of the design field of 10 T before a quench of the U1 coil brought the test to a halt. (Caveat on coil integrity: no tests > 8 T).

4.4 Single-coil AC tests

It was expected that a charge to 5.7 T (30 kA) at a ramp rate of 10 T/s would be achieved without evidence of transition from the superconducting to the normal state. However, an unexpected barrier of either field or current (or both) versus ramp rate was encountered. A secondary purpose, that of evaluating the cooling effectiveness of the dual-flow conductor, was pushed aside in favor of a focused look at the more important and completely unexpected ramp-rate limitation. It appeared on the basis of preliminary investigations during testing that the AC losses were too low to account for the ramp-rate limitation.

The "barrier" on performance is illustrated in Table 4.1, and when attempts were made to exceed these values, the coil quenched. It was found that the quenches initiated mainly in two places. At high ramp rates, the quenches initiated in the liquid-helium-cooled lap

Table 4.1 - Best performance in single-coil tests for trapezoidal-pulse runs ramped to fields from 3.8 T to 6.0 T (3 s flat tops without quench). Noncopper current density is defined as cable current divided by the cable noncopper area (approximately 50 mm^2).

run no.	ramp rate	field	current	J_c noncopper
139	19 T/s	3.8 T	20 kA	400 A/mm^2
128	4.3 T/s	4.3 T	23 kA	460 A/mm^2
122	2.7 T/s	4.7 T	25 kA	500 A/mm^2
124	0.71 T/s	5.7 T	30 kA	600 A/mm^2
134	0.55 T/s	6.0 T	32 kA	640 A/mm^2

joints, which are monolithic conductors for practical purposes. At lower ramp rates, the quenches initiated in the crossover turn of double pancake C, not in the peak field point of the magnet (crossover turn of B). It was noted that double pancake C had a void fraction of 43 % (larger helium inventory); the other two had void fractions of 38 %. Also, double-pancake C had a current-lead termination that was slightly damaged during fabrication. Figure 4.1 shows the baseline ramp-rate limit as described in section 10.3.1.

To better understand the observed behavior, the following charging waveforms were investigated: (1) two-step trapezoidal pulses; (2) multiple trapezoidal pulses; (3) round-edge trapezoidal pulses (ramp plus half sine wave); and (4) trapezoidal pulses with a superimposed ripple ranging from 6.6 to 16.5 Hz. Investigations were carried out under the nominal cooling conditions of 4.5 K, 6 atm, and 60 g/s. The highest current in the coil was achieved using a round-edge trapezoidal pulse. It was 35 kA (6.6 T) at an average ramp rate of 0.5 T/s.

To investigate the effect of cooling on the ramp limitation, improved cooling conditions were tried (4.0 K, 3.0 atm, 60 g/s); there was no significant improvement. Little difference was observed when the cable-space flow was reduced to zero in double pancake B, or when the corner flow was reduced to zero in pancake 4. Slow-flow cooling conditions were tried by reducing the inlet helium flow to 30 g/s (4.5 K, 6 atm). There was a noticeable, but small, improvement in performance (≈ 4 %).

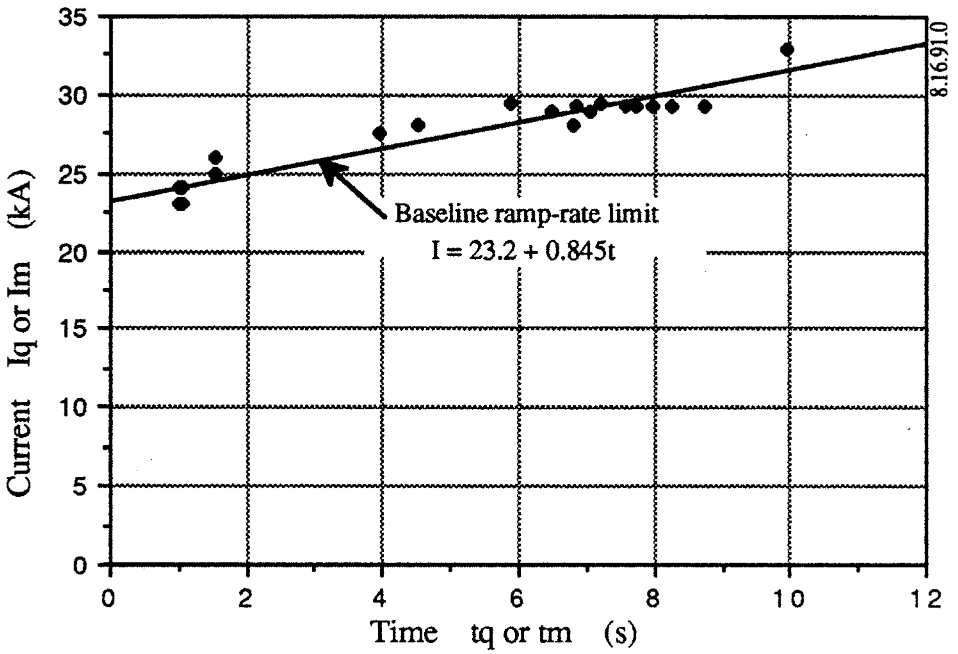


Figure 4.1 - Baseline ramp-rate limit defined as a straight line correlating quench data (see section 10.3.1).

4.5 Series-coil AC tests (US+U1+U2)

The principal purpose of the series AC tests was to determine if the coil could sustain a ramp rate of 10 T/s to a peak field of 10 T. It was found that it could not.

Four pulse shapes were used: triangular, trapezoidal, round-edge trapezoidal, and rippled trapezoidal. Note that only fast ramps were possible because of the limitations of the U1 and U2 coils. (The U1 and U2 coils would quench at ramps slower than approximately 3 s to currents of approximately 20 kA and above). The flow conditions were nominally 4 K, 6 atm, and 60 g/s at the inlet of the US-DPC (10 g/s per pancake). Table 4.2 summarizes the best performance based on pulses with flat tops, and Figure 4.2 plots the non-quenched series-coil runs in comparison with the baseline limit.

As an example of the temperature rise produced by AC losses and measured at the pancake outlets, run 265 in Table 4.2 is considered. The flow conditions were 4 K, 6 atm, 60 g/s. The trapezoidal pulse had a 1 s rise time, a 0.5 s flat-top time, and a 1 s fall time; it yielded an average outlet temperature rise of approximately 0.5 K on pancakes 2, 3 and 5. That is, the losses in the six pancakes were approximately equal.

Table 4.2 - Best performance in series-coil tests.

run no.	charging waveform	flattop	ramp rate	field	current	J_c noncopper
265	trapezoidal	0.5 s	6.4 T/s	6.4 T	21 kA	420 A/mm^2
271	round-edge trapezoidal	3.0 s	2.3 T/s (avg)	6.8 T	22 kA	440 A/mm^2
277	rippled trapezoidal	0.5 s	6.8 T/s (avg)	6.8 T	22 kA	440 A/mm^2

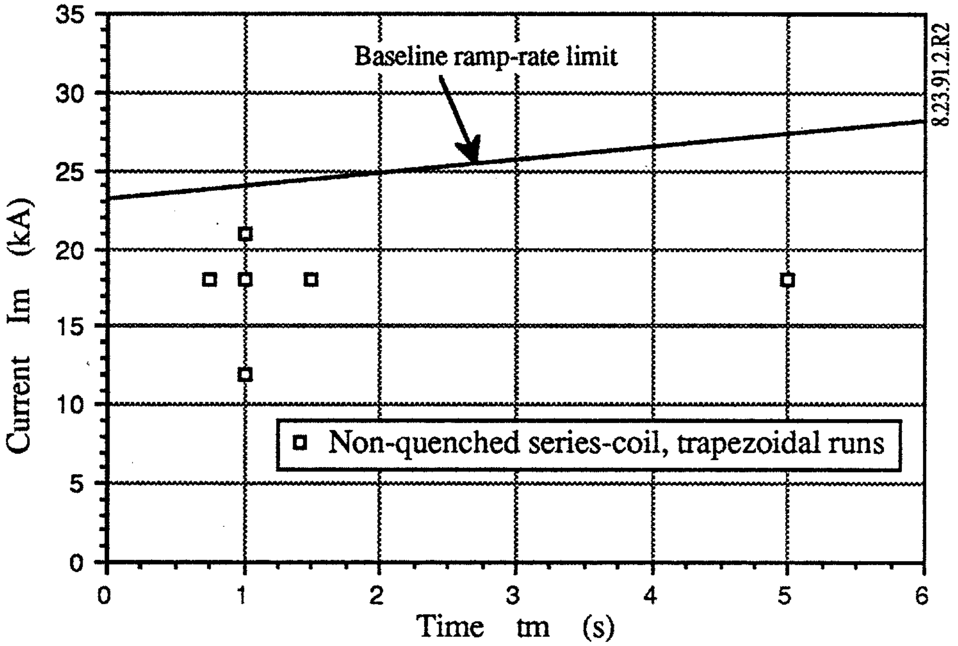


Figure 4.2 - Data of the non-quenched, series-coil, trapezoidal-pulse test runs fall below the baseline ramp-rate limit defined by single-coil data. Note, however, that the magnetic fields in the series-coil tests were higher.

The peak helium temperature rise has been estimated by JAERI from work on the DPC-EX to be approximately a factor of 3 - 4 times the outlet temperature rise. Thus, it is estimated that the trapezoidal pulse of run 265 produced a peak temperature rise in each crossover turn of roughly 2 K (absolute peak T ≈ 6 K).

5. Coil and test-mode specifications

Section 5 is a compilation of specifications of the wire, conductor, coil, coil stack, magnetic field distribution, and coolant flow arrangement. The relevant parameters of the US-DPC and its test arrangement at JAERI are described in detail.

5.1 Wire

The US-DPC wire, made by Teledyne Wah Chang Albany (TWCA), was a titanium-alloyed, internal-tin, modified-jelly-roll Nb_3Sn wire with a local copper-to-niobium ratio of 1.7 to 1. Parameters of the wire are given in Table 5.1. A cross section of the wire is shown in Figure 5.1.

Table 5.1 - Parameters of the TWCA internal-tin Nb_3Sn wire.

TWCA design designation	Cre 2000	Strand Diameter	0.78 mm
Volume % noncopper	46.0	Volume % copper	54.0
No. filament bundles	18	Strand pitch	12.7 mm
Strand chrome	2×10^{-6} m	Length/weight	242 m/kg
RRR	27		
Heat treatment:	220 C / 175 hrs + 340 /96 + 650 / 200		
Within the noncopper region:			
Volume % filament	22.9	Volume % copper	48.8
Volume % tin	15.8	Volume % vanadium	12.6
Local Cu/filament ratio	1.69		
Hysteresis (±3T cycle)[1]	460 mJ/cm^3-noncopper		
Coupling Time Constant	1 ms		
Hysteresis (±7T cycle)[1]	650 mJ/cm^3-noncopper		

Temperature dependence of hysteresis loss ($T \geq 4.5$ K)[2]: $Q_h = 1.47 - 0.103\ T$ [mJ/cm^3 - wire]

Hysteresis[3] - triangular wave to B_m: $Q_h = 178.2\{1 - \exp(-0.129\ Bm)\}$ [mJ/cm^3 - wire]

Bundle coupling[3] - triangular wave to B_m in time T_m:

$$Q_c = 50.68(B_m/T_m) \ln(1 + 2.4 \times 10^{-3}\ \mathrm{RRR}\ B_m) \quad [mJ/cm^3 - wire]$$

Critical current[3] (4.2 K, 10 μV/m) from B = 3 to 13 T:

$I_c = 1830.9 - 640.58\ B + 120.04\ B^2 - 12.707\ B^3 + 0.69682\ B^4 - 0.015336\ B^5$ with $R^2 = 1.000$, where R is the correlation coefficient.

5.2 Conductor

The cable-in-conduit conductor of the US-DPC consists of a 225-strand cable of multifilamentary Nb_3Sn wires enclosed in two conduits of Incoloy 908, a superalloy selected for its low coefficient of thermal expansion, which nearly matches that of Nb_3Sn. The ideal geometry of the conductor is shown in Figure 5.2. Table 5.2 lists parameters of the conductor.

5.3 Coil

The coil contains approximately 450 meters of conductor in the form of three double pancakes designated A - C connected electrically in series by means of resistive lap joints. Figure 5.3 shows the coil envelope and Figure 5.4 shows the connection schematic. The helium inlets are located at the midpoint, 75 meters from each end of a double pancake. The coil was designed to operate at 30 kA with an overall current density of 50 A/mm^2 at 10 T and 4 K. Table 5.3 summarizes the coil design.

Figure 5.5 shows a plan view of the coil and centerline geometry of a double pancake. Each pancake has a conductor geometry defined by offset semicircles. The helium inlet of a double pancake is at the 180 degree reference at the inner diameter. As can be seen in

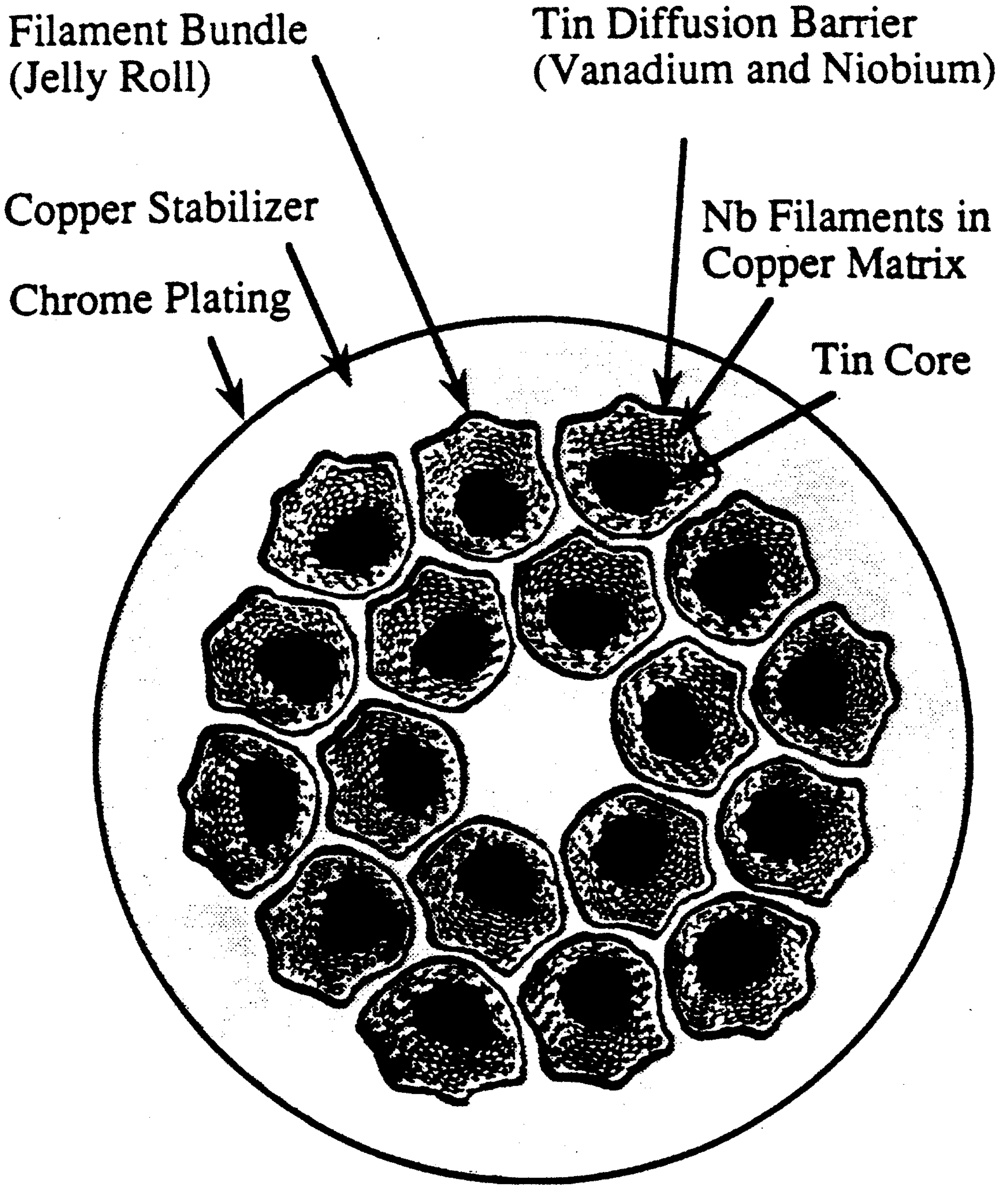


Figure 5.1 - Cross sectional view of unreacted US-DPC internal-tin modified jelly roll Nb_3Sn wire. The diameter is 0.78 mm; 54% is copper; there are 18 filament bundles.

Figure 5.5 (b), only 50 % of the conductor centerlines are on arcs with centers at the "true coil center". Note that the double pancakes are stacked so that two helium inlets (A and C) are located opposite the current leads and one helium inlet (B) is located adjacent to the current leads. That is, the 180 degree reference point of double pancake A and C are located just above and below the 0 degree reference point of double pancake B.

The centerline radii are given in Table 5.4. Note that the crossover turn from 270-to-0-to-90 degrees has a center offset of 15 mm. All other turns have an offset of 11.5 mm. The crossover turn spans 360 degrees; we associate one half of a crossover turn with each pancake (16.5 turns per pancake). The primed radii define arcs from 270-to-0-to-90 degrees; the unprimed from 90-to-180-to-270 degrees.

The insulation geometry at a double pancake "180 degree reference" is shown in Figure 5.6. At this location, the inside radius of the groundwall insulation is 500 mm; the inside radius of the crossover is 506.85 mm.

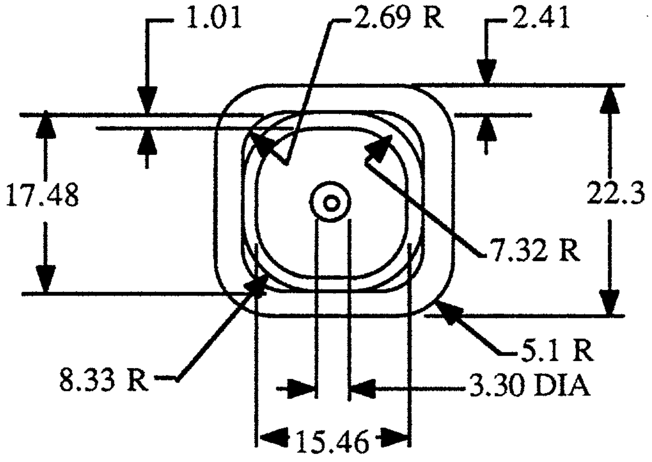


Figure 5.2 - Dimensions of the US-DPC conductor in millimeters. There were full-length heater wires (3.30 mm dia. x 150 m) in two of the three double pancakes (A and B).

Table 5.2 - Parameters of the US-DPC cable-in-conduit conductor (CICC).

Void Fraction (no heater)	43%	Void Fraction (with heater)*	38%
Cable space area	193.0 mm^2	Cable area	108.6 mm^2
Cable helium area (no heater)	82.9 mm^2	Cable helium area (with heater)	74.3 mm^2
Inner conduit area	53.0 mm^2	Outer conduit area	175.4 mm^2
Corner helium area	53.6 mm^2	Number strands	225
Cable type	3x3x5x5	Strand pitch	12.7 mm
Triplet pitch	51 mm	3x3 pitch	102 mm
3x3x5 pitch	203 mm	3x3x5x5 pitch	305 mm
Actual strand diameter	0.78 mm		

* Two of the three cables had 3.2 mm diameter heater wires at their centers.

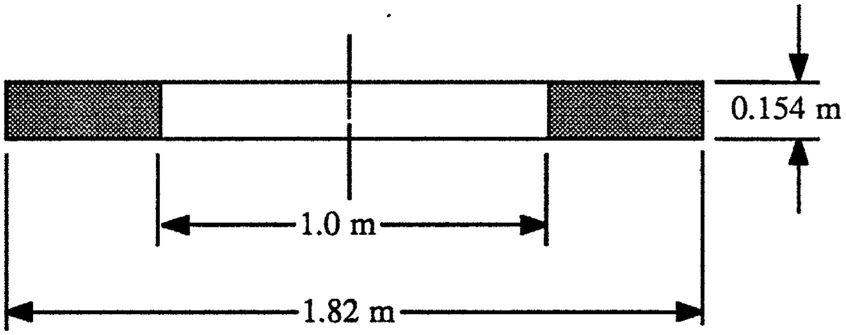


Figure 5.3 - Envelope dimensions of the US-DPC solenoid. The two lap joints between the three double pancakes are not shown.

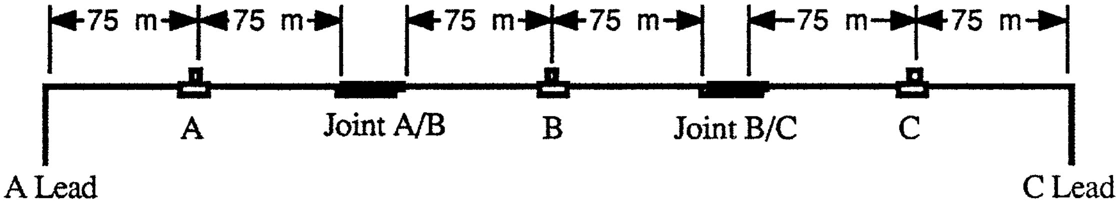
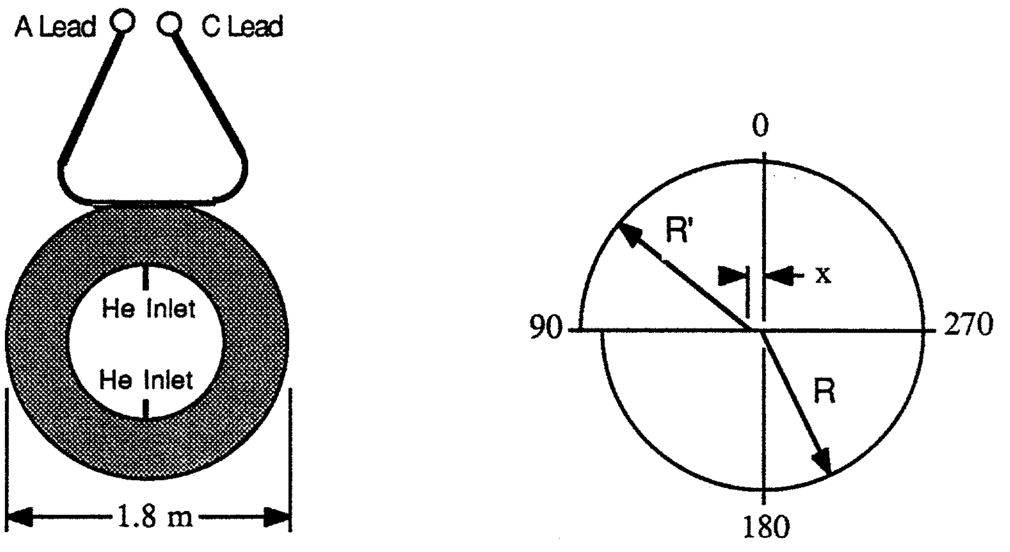


Figure 5.4 - Connection schematic showing the helium inlet tees of the A, B, C double pancakes, the A/B and B/C lap joints and the coil leads.

Table 5.3 - Summary of the US-DPC coil design.

Superconductor	Nb_3Sn	Conduit	Incoloy 908
Design field	10 T	Design current	30 kA
Design ramp rate	10 T/s	Double pancakes	3
Height	0.154 m	Turns per double pancake	33
Total turns*	100	Ampere-turns	3 MA
Inner diameter	1.0 m	Outer diameter	1.8 m
Total conductor length	450 m	Length per double pancake	150 m
Overall current density	50 A/mm^2	Cable-space current density	163 A/mm^2
Turn-to-turn insulation	0.71 mm	Ground insulation	1.88 mm
Barrier disk between pancakes	2.44 mm	Load line (single coil mode)	0.190 T/kA
Load line (series mode)	0.307 T/kA		

* Includes turn for lap joints between double pancakes



(a) Plan view of US-DPC coil. (b) Conductor centerline geometry.

Figure 5.5 - Reference coordinates of the US-DPC. The assembled coil is shown in (a) and the centerline geometry of a double pancake in (b). Note that each double pancake consists of semicircles with the top semicircle offset from the bottom by a distance x. The helium inlets of the A and C double pancakes are opposite the current leads and that of the B double pancake adjacent to the current leads.

Table 5.4 - Centerline radii of each double pancake. Unprimed radii are from the true center; primed radii are from the offset center.

	Bottom Arcs (90/180/270)	Top Arcs (270/0/90)
Crossover		
	R_0 = 518 mm	R_0' = 533 mm
Other turns		
	R_1 = 548 mm	R_1' = 559.5 mm
	R_2 = 571 mm	R_2' = 582.5 mm
	R_3 = 594 mm	R_3' = 605.5 mm
	⋮	⋮
	R_{15} = 870 mm	R_{15}' = 881.5 mm
	R_{16} = 893 mm	R_{16}' = 904.5 mm

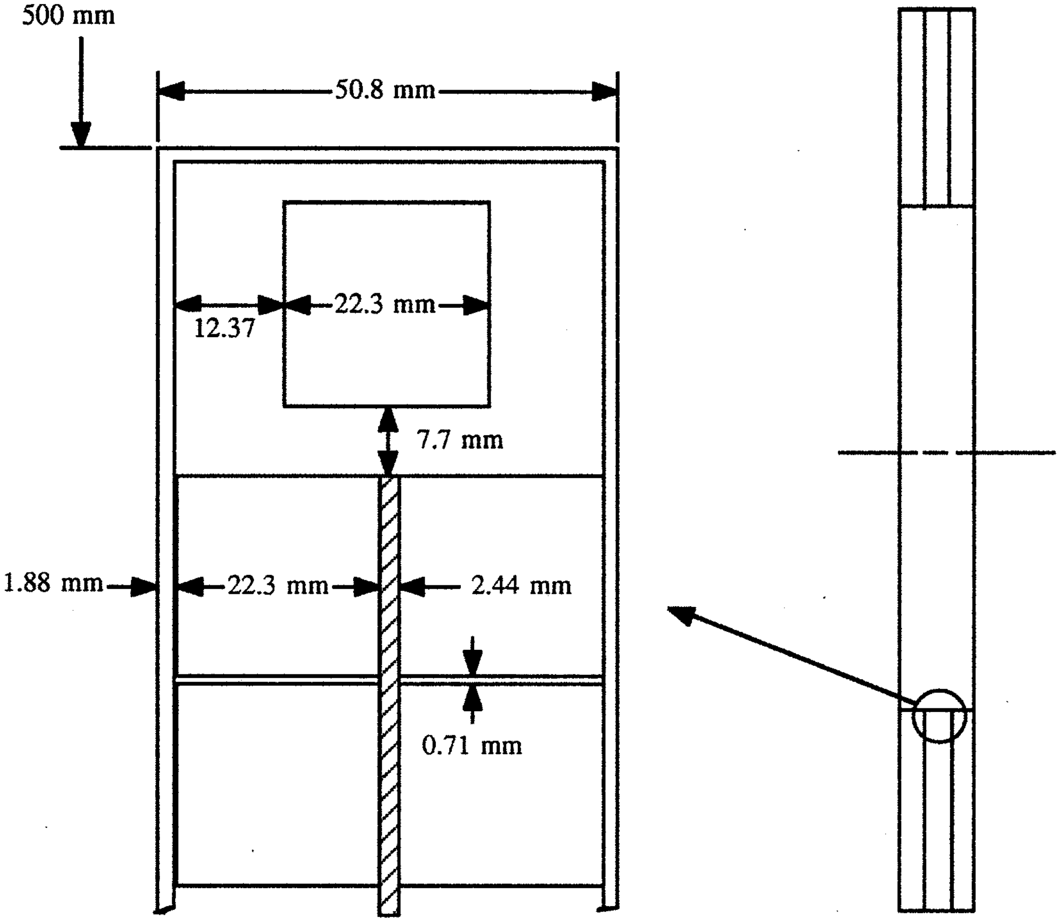


Figure 5.6 - The double pancake cross section at the 180 degree reference of Figure 4.5 (b) shows the insulation builds (helium inlet is not pictured in the cross section). The inside radius of the ground wall is 500 mm. Insulation is epoxy-glass.

5.4 Coil stack

The geometry of US-DPC, U1, and U2 coils in the JAERI test facility is outlined in Table 5.5. The inner radius is approximately 510 mm to the conduit metal; the axial height includes turn and ground insulation (for U1 and U2 this is 4.5 mm gnd + 0.5 mm turn and for US-DPC this is 1.9 mm gnd). In Table 5.5, the inner and outer radii of the US-DPC are average values taken from the true center.

5.5 Magnetic field distribution

The magnitude of the calculated magnetic fields as a function of radius for the single-coil and series-coil test modes are given in this section.

The field distribution along the midplane of each pancake in the single-coil mode (no background field) has been calculated assuming the following envelope geometry: inner radius to conduit metal of 510 mm, outer radius of 910 mm, and height of 154 mm. The envelope was assumed to contain 100 turns, yielding an overall current density at 30 kA of approximately 48.7 MA/m^2. The midplanes of the pancakes are positioned at 12.7 mm, 38.9 mm, and 64.3 mm; these are the elevations at which the field as a function of radius is calculated. Figure 5.7 plots the magnitude of field as a function of radius at the three elevations for the single-coil mode (US-DPC only). Figure 5.8 plots the field as a function of radius for the series-coil mode (U1 + US-DPC + U2). The peak field, located at the inner edge of the crossover turn of double pancake B, is approximately 5.66 T at 30 kA for the single-coil mode and 9.22 T at 30 kA for the series-coil mode.

Table 5.5 - Coil-stack geometry of the US-DPC and the JAERI U1 and U2 coils.

coil	inner radius (mm)	outer radius (mm)	axial height (mm)	axial position (mm)	operating current (kA)	no. of turns
US-DPC	510 [1]	910	154 [2]	0 (± 77) [3]	30	100 [4]
DPC-U1	500	1010	313.4	207.7, 521.1	30	127
DPC-U2	500	1010	313.4	- 207.7, - 521.1	30	127

[1] inner radius is 500 mm to insulation and 510 mm to conduit metal at 180° reference

[2] includes two 0.8 mm G10 sheets between double pancakes

[3] z = 0 corresponds to the US-DPC midplane

[4] 33 turns per double pancake plus 1 turn for lap joints

5.6 Flow

Secondary cooling passages were provided by the four corners between the inner conduit and the outer conduit (see Figure 5.2). In double pancake B (pancakes 3 and 4), the cable-space and corner flows were controlled separately by means of valves. Three cooling modes were thus possible: (1) flow through the cable with zero flow in the corners, (2) flow in the corners with zero flow in the cable, and (3) flow through both the cable and corners. The "normal" flow condition in double pancake B was with all outlet valves open (valves V2 through V5). The nominal inlet flow condition was supercritical helium at 4.5 K, 6 atmospheres absolute, and 60 g/s. See Figure 5.9 for the supercritical helium flow diagram.

Note that although the nominal flow was 60 g/s as measured by a flow meter monitoring the total flow into the US-DPC, the sum of the individual flow measurements of each double pancake varied markedly. The total flow obtained by summing the individual flows was nominally 45 g/s. Furthermore, the mass flows at the inlet of A (pancakes 1 and 2) and B (pancakes 3 and 4) should be the same because the flow cross-sections are the same. However, double pancake A's flow is approximately 75% of B's flow. Also, the outlet flows of B do not sum to equal the inlet flow of B. There is a consistent discrepancy throughout the testing, indicating a need for thorough calibration of the flow meters throughout the measuring range in future tests.

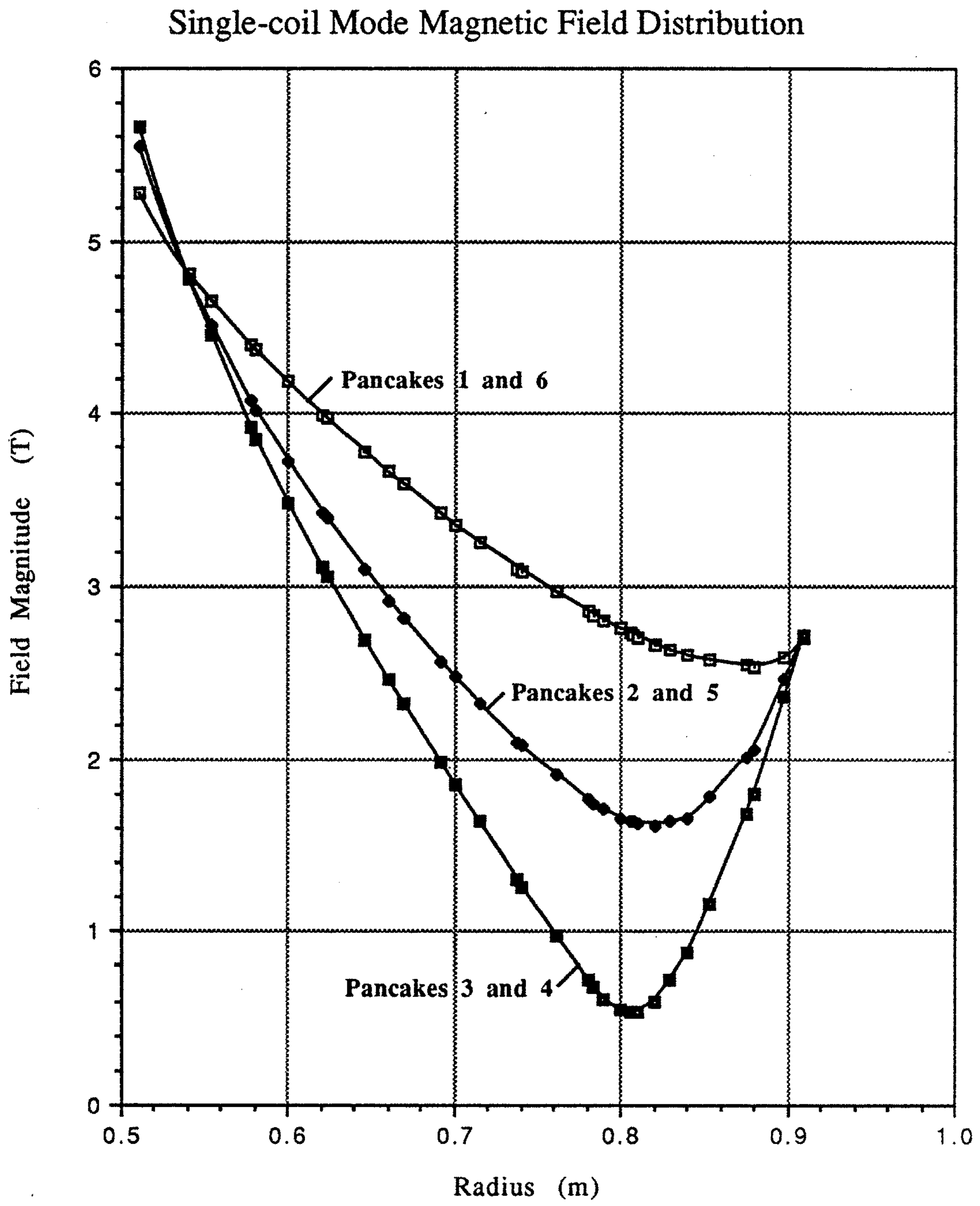


Figure 5.7. - Absolute value of magnetic field as a function of radius plotted along the midplanes of the US-DPC pancakes at 30 kA. The plot is for the single-coil mode (US-DPC only). The midplanes of pancakes 1 and 6 are at elevations of ± 64.3 mm, 2 and 5 at ± 38.9 mm, and 3 and 4 at ± 12.7 mm. The peak field at the inner edge of the crossover turn of double pancake B is approximately 5.66 T at 30 kA.

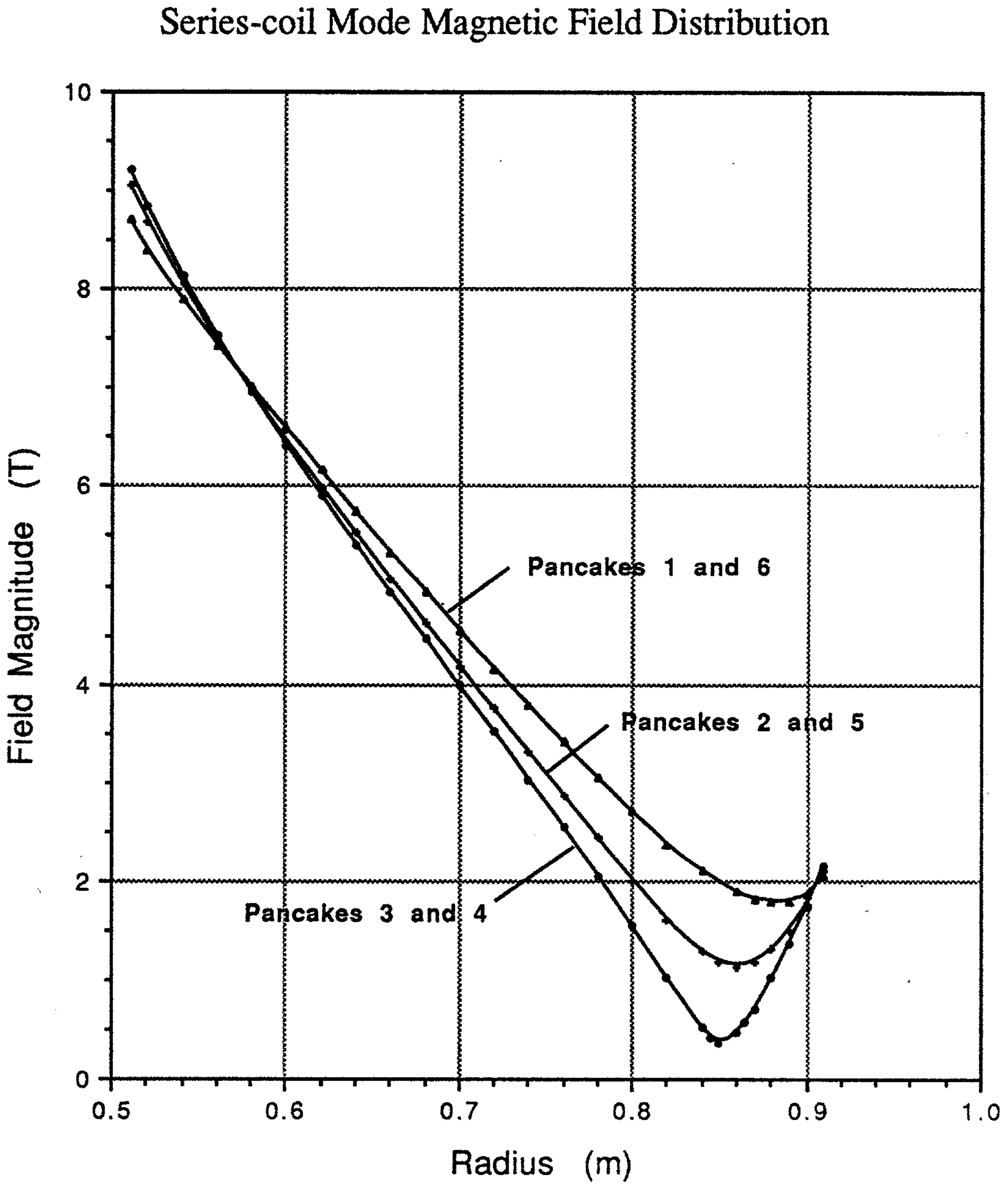
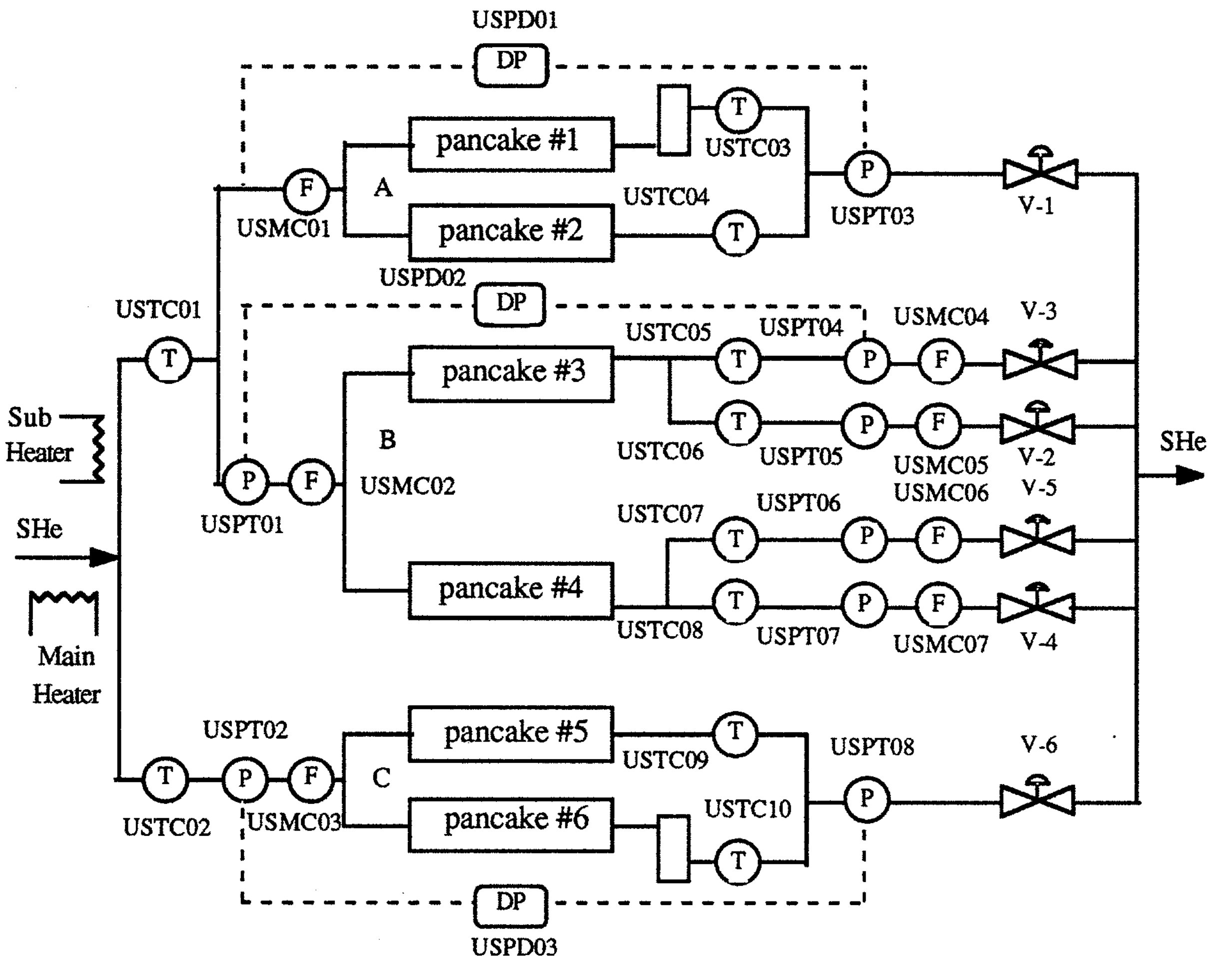


Figure 5.8 - Absolute value of magnetic field as a function of radius plotted along the midplanes of the US-DPC pancakes at 30 kA. The plot is for the series-coil mode (U1 + US-DPC + U2). The midplanes of pancakes 1 and 6 are at elevations of ± 64.3 mm, 2 and 5 at ± 38.9 mm, and 3 and 4 at ± 12.7 mm. The peak field at the inner edge of the crossover turn of double pancake B is approximately 9.22 T at 30 kA.



Legend: T = temperature (carbon glass resistors)
P = pressure (room-temperature pressure transducers)
F = mass flow (orifice flow meters)

Figure 5.9 - Supercritical helium flow schematic of the US-DPC. There were 10 temperature, 8 pressure, and 7 flow measurement points. Outlets in pancakes 3 and 4 were piped to allow independent control of flow in the corners and cable space (see Figure 5.2). Valves V-3 and V-4 controlled cable space flow; V-2 and V-5 controlled corner flow in double pancake B.

References

1. R. Goldfarb, Private communication.

2. A.K. Ghosh and M. Suenaga, IEEE Trans. Mag., Vol. 27, No. 2, March 1991, p. 2407.

3. M. Takayasu et al., "11th Int'l Conf. on Magnet Tech.", (1989), p. 1033.

6. Thermal performance

6.1 Introduction

The cooldown performance, coil heat load measurements, and pressure drop performance were measured to characterize the thermal performance of the US-DPC. In the cooldown operation, it was demonstrated how to cool a large-scale, forced-cooled, cable-in-conduit conductor to the 4K regime with no resultant damage from excessive thermal stress in the coil. The coil heat loads were estimated by measuring the enthalpy differences between the inlet and outlet helium of the coil. The pressure drop performance across the coil is of interest for future designs of force-cooled, cable-in-conduit conductors. Through the US-DPC experiments, Reynolds numbers and friction factors were calculated by measuring the coil pancake mass flow rate and the differential pressure between the pancake inlet and outlet.

6.2 Cooldown

6.2.1 Cooldown weight

The US-DPC, DPC-U1, and U2 were assembled in coaxial configuration as shown in Figure 6.1. The total cooldown weight including the coil suppport structure system was around 23 tons as listed in Table 6.1.

6.2.2 Cooldown operation

The US-DPC, DPC-U1, DPC-U2, and the cryogenic pump system, which circulates supercritical helium through the coil system, were simultaneously cooled down to temperatures less than 20 K by using JAERI's 1.2-kW, 350-liter/hour helium refrigerator. Below 20 K, the cryogenic pump system supplied 4 K liquid helium to the coil system. The cooldown flow scheme and method is shown in Figure 6.2.

From room temperature to 90 K, the helium supply temperature was controlled to prevent excessive thermal stresses in the coil by monitoring the temperature throughout the coil system at more than 70 locations. From 90 K to 20 K, the cooldown was limited only by the refrigeration power of the cryogenic system.

6.2.3 Cooldown performance

6.2.3.1 Cooldown performance curve

The helium supply temperature, inlet helium temperature, and outlet helium temperature were measured as a function of cooldown time as shown in Figure 6.3. The helium supply temperature was reduced in a step-like manner by computer control. Up to 50 hours after the cooldown had begun, the coil outlet temperature decreased with the rate of -0.6 K/h. From 50 hours to 100 hours, the cooldown rate was around -3 K/h, and from 100 hours to 150 hours, when the computer control was stopped, the rate was around -1.6 K/h. The cooldown from room temperature to below 20 K was completed in 150 hours.

During cooldown, the mass flow rate to the US-DPC was continuously monitored to maintain the differential pressure across the coil to less than 0.2 MPa. The mass flow rate

Table 6.1 - Cooldown weight of DPC coil system.

COOLDOWN WEIGHT

Superconducting coil	U1/U2 coil US coil	4200kg x 2 2800kg
Supporting structure	Coil supprt Supprt frame Support legs FRP etc.	7400kg 2700kg 350kg 300kg
Total		23000kg

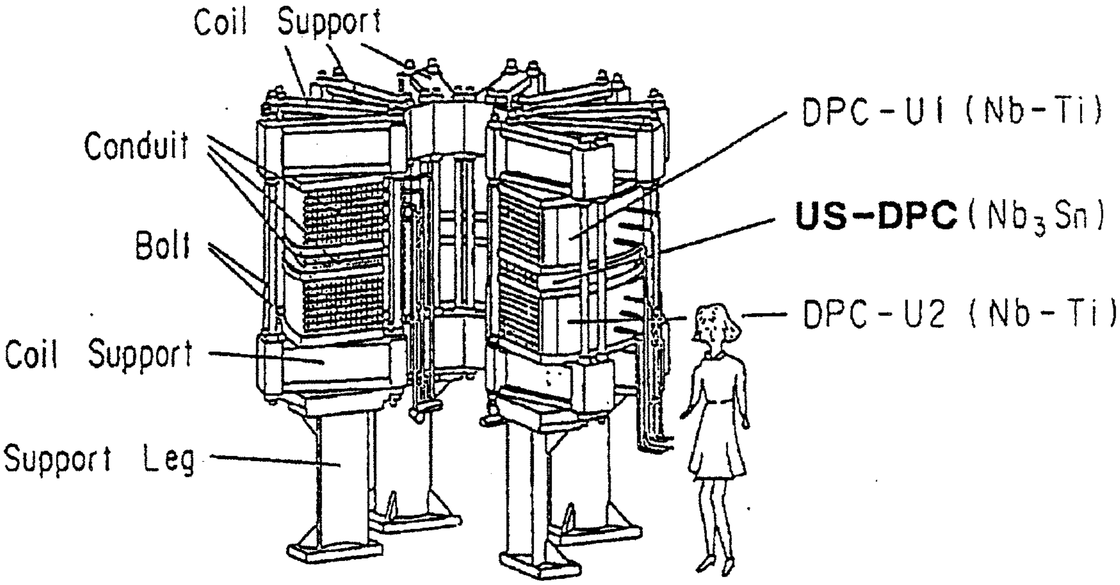
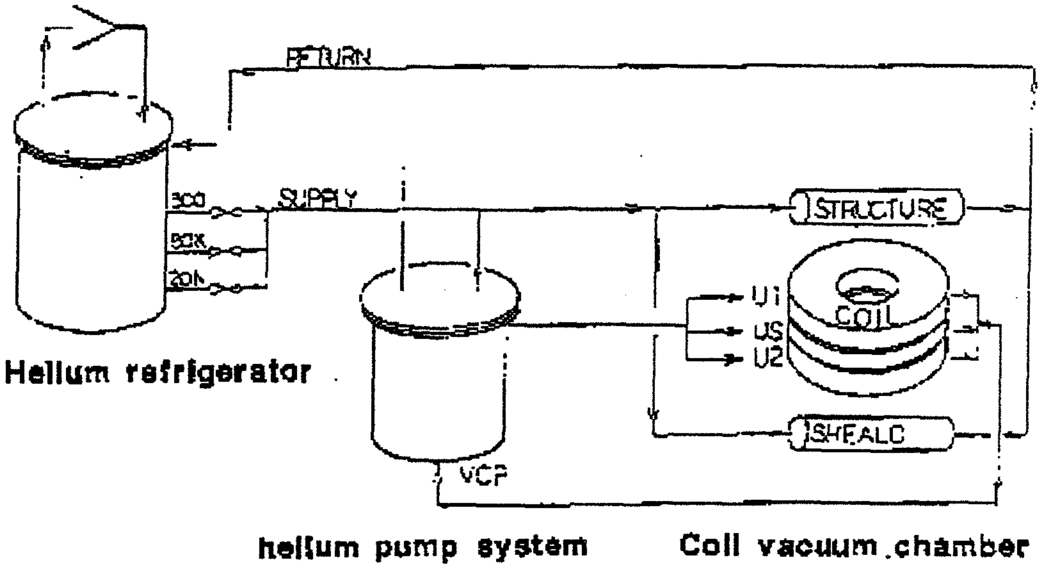


Figure 6.1 - Coil configuration of the US-DPC, DPC-U1, and DPC-U2.

COOLDOWN OPERATION



COIL TEMP.	OPERATION
300 - 90 K	AUTOMATIC CONTROL BY COMPUTER
90 - 60 K	COLD TURBINE START
60 - 20 K	WARM TURBINE START
20 - 4 K	SHe CIRCULATION PUMP START

Figure 6.2 - Cooldown flow scheme and method.

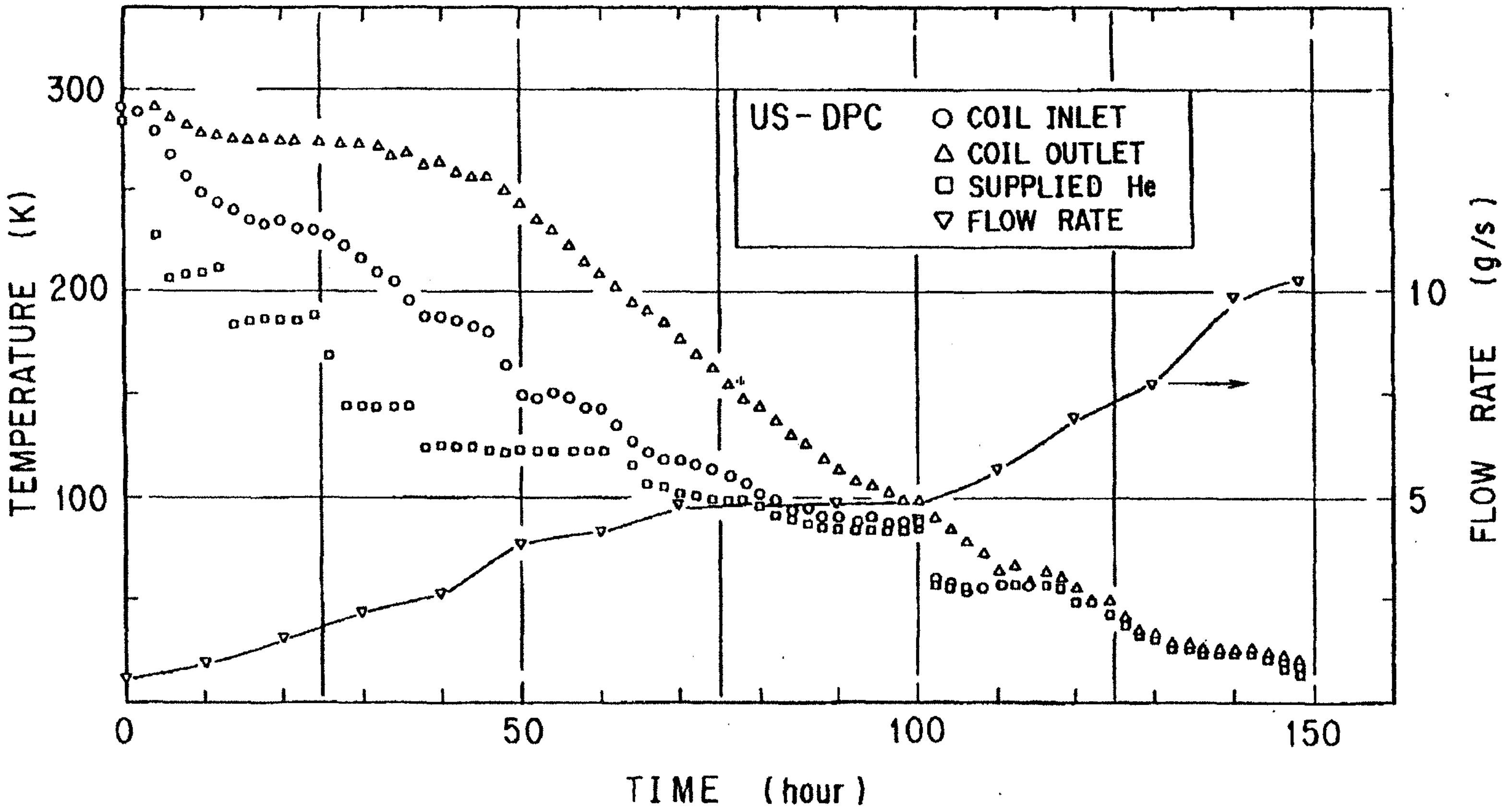


Figure 6.3 - Coil cooldown temperature characteristics as a function of time.

was changed from a few grams per second in the beginning to around 10 g/s at the end of the cooldown as shown in Figure 6.3.

After cooldown, it was verified that no damage from excessive thermal stress was done to the coil.

6.2.3.2 Cooldown temperature control specifications

The temperature during cooldown was controlled according to the following specifications.

1) The temperature difference between the pancake inlet and the outlet was kept below 100 K.
2) The temperature difference between the US-DPC and neighboring coils (DPC-U1 and U2) was kept below 50 K.

The results of the temperature control during cooldown are shown in Figure 6.4 for the pancake inlet and outlet temperature differences and Figure 6.5 for the coil temperature differences. The maximum temperature difference between the pancake inlet and outlet was 100 K at the cooldown time of 50 hours, which corresponds to the thermal stress of around 2 kgf/mm^2 (around 0.2 MPa). The temperature difference profiles as a function of the cooldown time were similar in each pancake.

The maximum temperature difference between the US-DPC and the neighboring coils was around 50 K at pancake No. 1 of the US-DPC at the cooldown time of 50 hours.

The control specifications mentioned above were maintained throughout the cooldown.

6.3 Coil heat load measurements

6.3.1 Sensors and locations

To measure the coil thermal conditions, seven flow meters, eight pressure taps, and 18 temperature sensors were installed as shown in Figure 6.6. An orifice type flow meter was adopted as the mass flow meter, the measurement ranges in the 4 K regime were 3 to 20 g/s for the two flow meters (USMC01 - 02) located at the inlet of double pancakes A and B, 6 to 40 g/s for the flow meter at the inlet of double pancake C (USMC03) and 1 to 10 g/s for the four flow meters (USMC04 - 07) located at the outlet of the double pancakes. Platinum-Cobalt thermocouples were used at temperatures above 20 K, and carbon-glass resistor thermocouples were used at temperatures below 20 K.

6.3.2 Coil heat load measurement results

Similar to the AC loss measurements (see Appendix B), the coil heat load can be calculated by measuring the increase in helium enthalpy from the coil inlets to the outlets and multiplying by the mass flow rate of the given flow channel.

In the experiment, the helium enthalpies were found by measuring the helium pressures and temperatures at the coil inlets and the outlets. The enthalpy difference between the inlet and outlet was then multiplied by the mass flow of the given channel to find the heat load of that particular channel. Finally, the total coil heat load was found by summing the heat loads of the individual flow channels.

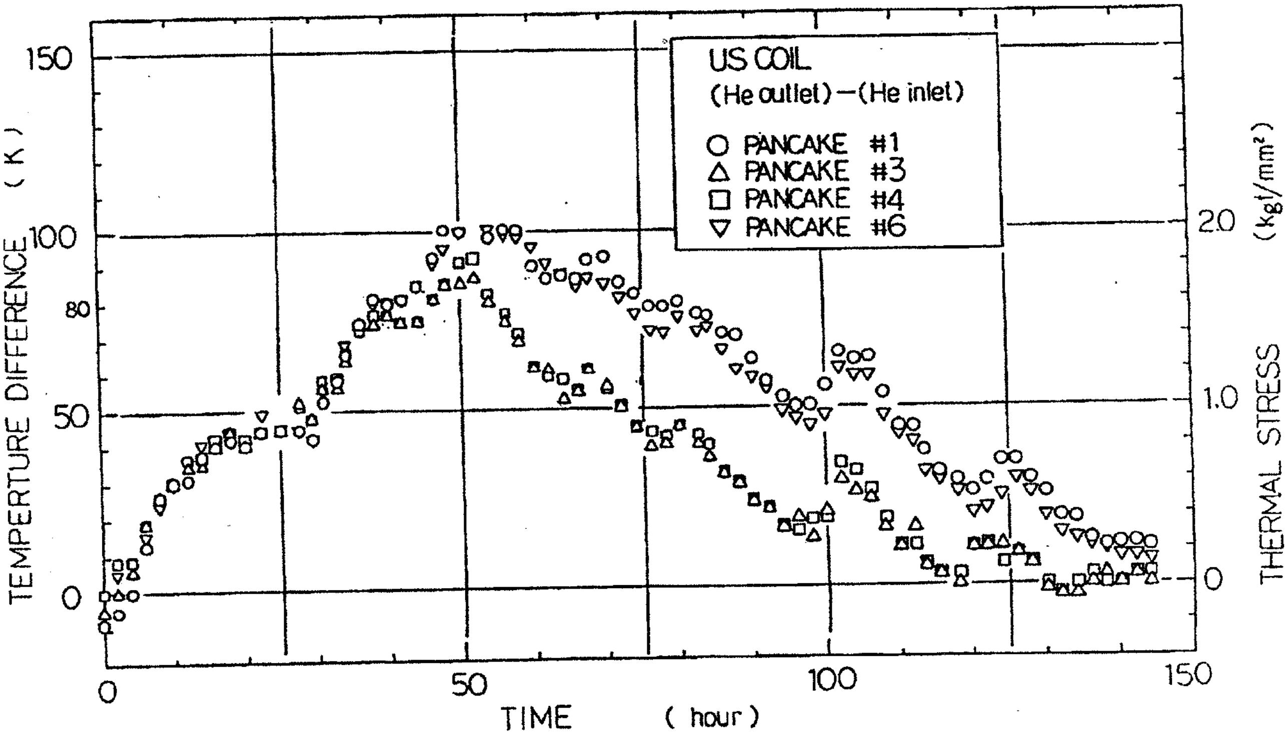


Figure 6.4 - Temperature difference between inlet and outlet of US-DPC pancakes 1, 3, 4 and 6 as a function of cooldown time.

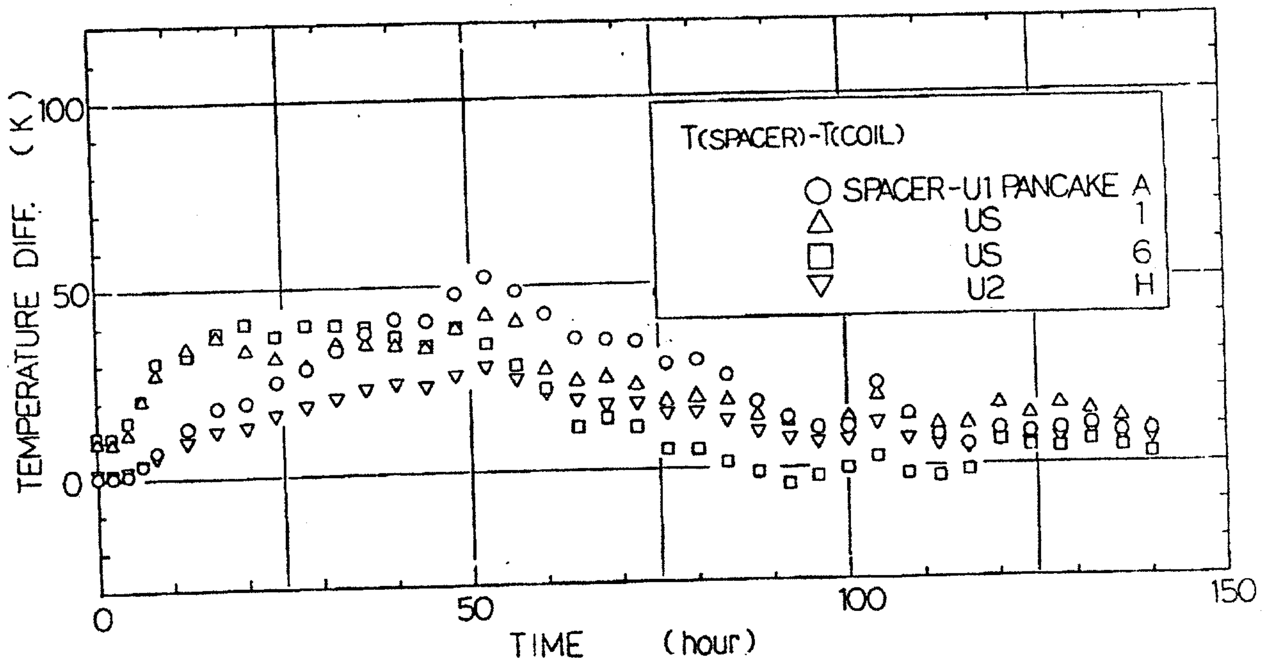


Figure 6.5 - Temperature difference between coil spacer and US pancake 1, US pancake 6, U1 pancake A and U2 pancake H as a function of cooldown time..

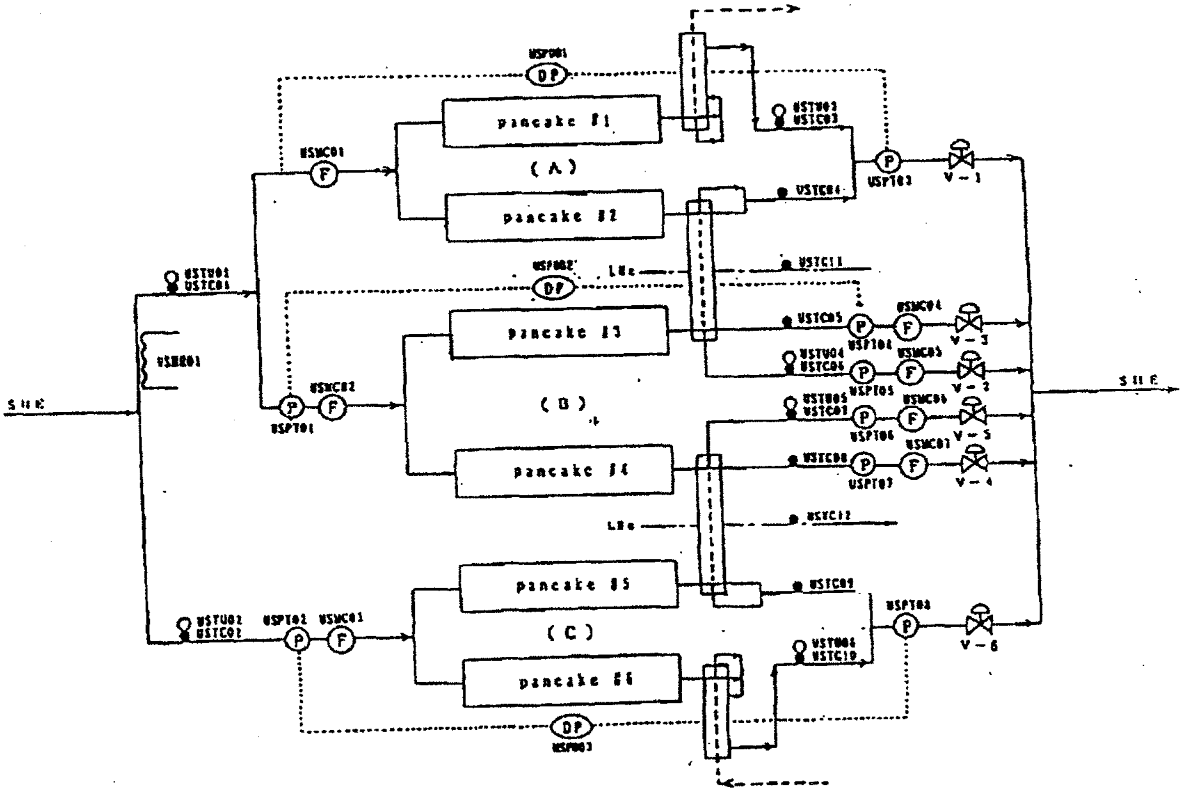


Figure 6.6 - Cooling flow diagram of US-DPC and sensor locations.

The coil heat load calculation results are shown in Table 6.2 (a) to (e), which are selected for the five typical operation modes:

(a) Standby mode with the current leads cooled by cold helium vapor.

(b) US-DPC was charging at 30 kA with the current leads cooled by liquid helium.

(c) US-DPC was charging at 25 kA and heater input of 70 + 353 W with the current leads cooled by liquid helium.

(d) US-DPC was charging at 30 kA and heater input of 100 W with the current leads cooled by cold helium vapor.

(e) US-DPC, DPC-U1, and U2 were charging at 25 kA in series with the current leads cooled by liquid helium.

Pancakes No. 1 and No. 6 (see Figure 6.6) are connected to the negative and positive current leads, respectively. Thus, pancakes No. 1 and No. 6 are subjected to heat conduction from the current lead which is, in turn, strongly affected by the current lead cooling condition.

Table 6.2 - (a) Coil heat load calculation results in standby mode with the current leads cooled by cold helium vapor.

No. 26	Date 12/ 5	Time 6:43	Stand by Mode

Coil	Pancake		Flow g/s	P in atm	T in K	H in J/g	P out atm	T out K	H out J/g	Heat Load W
U S	# 1		1.50	5.729	4.816	13.68	5.661	5.173	15.38	2.6
	# 2		1.50	5.729	4.816	13.68	5.661	4.709	13.20	-0.7
	# 3	Center	0.31	5.729	4.816	13.68	5.663	4.808	13.62	0.0
		Corner	1.01	5.729	4.816	13.68	5.631	4.633	12.88	-0.8
	# 4	Corner	1.00	5.729	4.816	13.68	5.608	4.701	13.15	-0.5
		Center	0.47	5.729	4.816	13.68	5.621	4.697	13.14	-0.3
	# 5		1.71	5.729	4.661	13.03	5.637	4.591	12.72	-0.5
	# 6		1.71	5.729	4.661	13.03	5.637	9.284	51.76	66.0
C/L Cooling = Gas						Estimated Total Heat Load				65.7
U 1	# A		3.32	5.497	4.629	12.81	5.468	5.961	20.23	24.6
	# B		5.92	5.497	4.629	12.81	5.514	4.772	13.41	3.6
	# C		2.32	5.497	4.629	12.81	5.514	4.772	13.41	1.4
	# D		2.32	5.497	4.629	12.81	5.434	4.765	13.35	1.3
	# E		3.53	5.497	4.629	12.81	5.434	4.765	13.35	1.9
	# F		3.53	5.497	4.629	12.81	5.440	4.666	12.94	0.5
	# G		4.82	5.497	4.629	12.81	5.440	4.666	12.94	0.6
	# H		0.50	5.497	4.629	12.81	5.471	6.231	22.58	4.9
C/L Cooling = Gas						Estimated Total Heat Load				38.7
U 2	# A		3.00	5.533	4.626	12.82	5.544	6.605	26.54	41.2
	# B		2.39	5.533	4.626	12.82	5.474	4.759	13.34	1.2
	# C		3.00	5.533	4.626	12.82	5.474	4.759	13.34	1.6
	# D		3.00	5.533	4.626	12.82	5.426	4.683	13.01	0.6
	# E		3.05	5.533	4.626	12.82	5.426	4.683	13.01	0.6
	# F		3.05	5.533	4.626	12.82	5.400	4.677	12.97	0.5
	# G		2.73	5.533	4.626	12.82	5.400	4.677	12.97	0.4
	# H		2.79	5.533	4.626	12.82	5.416	5.705	18.40	15.6
C/L Cooling = Gas						Estimated Total Heat Load				61.5

Table 6.2 - (b) Coil heat load calculation results while the US-DPC was charging at 30 kA with the current leads cooled by liquid helium.

No. 8	Date 11/16	Time 19:28	US Single 30 kA

Coil	Pancake		Flow g/s	P in atm	T in K	H in J/g	P out atm	T out K	H out J/g	Heat Load W
U S	# 1		10.12	6.601	4.164	11.68	5.733	4.624	12.89	12.2
	# 2		10.12	6.601	4.164	11.68	5.733	4.545	12.58	9.1
	# 3	Center	1.06	6.601	4.164	11.68	6.584	5.812	18.94	7.7
		Corner	5.76	6.601	4.164	11.68	5.679	4.392	12.00	1.8
	# 4	Corner	5.95	6.601	4.164	11.68	5.705	4.351	11.87	1.1
		Center	0.94	6.601	4.164	11.68	6.592	5.387	16.66	4.7
	# 5		12.04	6.601	4.117	11.53	5.637	4.161	11.20	-4.0
	# 6		12.04	6.601	4.117	11.53	5.637	4.471	12.27	8.9
C/L Cooling = Liquid						Estimated Total Heat Load				41.6
U 1	# A		5.49	5.754	4.271	11.62	4.536	5.326	16.13	24.8
	# B		11.03	5.754	4.271	11.62	5.630	4.401	12.01	4.3
	# C		6.89	5.754	4.271	11.62	5.630	4.401	12.01	2.7
	# D		6.89	5.754	4.271	11.62	5.550	4.408	12.00	2.6
	# E		7.68	5.754	4.271	11.62	5.550	4.408	12.00	2.9
	# F		7.68	5.754	4.271	11.62	5.579	4.324	11.72	0.8
	# G		9.47	5.754	4.271	11.62	5.579	4.324	11.72	0.9
	# H		4.56	5.754	4.271	11.62	5.539	5.643	17.98	29.0
C/L Cooling = Gas						Estimated Total Heat Load				68.0
U 2	# A		6.64	5.702	4.263	11.57	5.714	5.447	16.83	34.9
	# B		6.27	5.702	4.263	11.57	5.498	4.383	11.89	2.0
	# C		7.27	5.702	4.263	11.57	5.498	4.383	11.89	2.3
	# D		7.27	5.702	4.263	11.57	5.523	4.334	11.73	1.2
	# E		7.14	5.702	4.263	11.57	5.523	4.334	11.73	1.1
	# F		7.14	5.702	4.263	11.57	5.521	4.332	11.72	1.1
	# G		8.76	5.702	4.263	11.57	5.521	4.332	11.72	1.3
	# H		5.09	5.702	4.263	11.57	5.744	5.244	15.77	21.4
C/L Cooling = Gas						Estimated Total Heat Load				65.3

Table 6.2 - (c) Coil heat load calculation results while the US-DPC was charging at 25 kA and heater input of 70 + 353 W with the current leads cooled by liquid helium.

No. 23	Date 11/22	Time 11:24	US 25 kA with Heater 70+353W

Coil	Pancake		Flow g/s	P in atm	T in K	H in J/g	P out atm	T out K	H out J/g	Heat Load W
U S	# 1		1.77	8.165	9.736	50.65	7.981	7.476	31.05	-34.6
	# 2		1.77	8.165	9.736	50.65	7.981	9.176	46.57	-7.2
	# 3	Center	0.00	8.165	9.736	50.65	7.985	8.626	41.94	0.0
		Corner	1.04	8.165	9.736	50.65	7.972	9.156	46.40	-4.4
	# 4	Corner	1.17	8.165	9.736	50.65	7.952	8.975	44.95	-6.7
		Center	0.96	8.165	9.736	50.65	7.971	8.583	41.59	-8.7
	# 5		3.88	8.165	8.356	39.23	7.935	8.131	37.52	-6.6
	# 6		3.88	8.165	8.356	39.23	7.935	7.503	31.37	-30.5
C/L Cooling = Liquid						Estimated Total Heat Load				-98.7
U 1	# A		5.49	7.838	4.560	13.57	7.642	5.447	17.21	20.0
	# B		10.25	7.838	4.560	13.57	7.710	4.713	14.07	5.1
	# C		5.25	7.838	4.560	13.57	7.710	4.713	14.07	2.6
	# D		5.25	7.838	4.560	13.57	7.675	4.703	14.02	2.4
	# E		6.42	7.838	4.560	13.57	7.675	4.703	14.02	2.9
	# F		6.42	7.838	4.560	13.57	7.660	4.630	13.74	1.1
	# G		7.69	7.838	4.560	13.57	7.660	4.630	13.74	1.3
	# H		3.94	7.838	4.560	13.57	7.645	6.231	21.41	30.9
C/L Cooling = Gas						Estimated Total Heat Load				66.3
U 2	# A		6.48	7.734	4.545	13.47	7.440	6.405	22.59	59.1
	# B		4.68	7.734	4.545	13.47	7.626	4.680	13.91	2.1
	# C		5.74	7.734	4.545	13.47	7.626	4.680	13.91	2.5
	# D		5.74	7.734	4.545	13.47	7.628	4.625	13.71	1.4
	# E		6.34	7.734	4.545	13.47	7.628	4.625	13.71	1.5
	# F		6.34	7.734	4.545	13.47	7.581	4.635	13.72	1.6
	# G		6.19	7.734	4.545	13.47	7.581	4.635	13.72	1.5
	# H		5.47	7.734	4.545	13.47	7.660	5.720	18.55	27.8
C/L Cooling = Gas						Estimated Total Heat Load				97.5

Table 6.2 - (d) Coil heat load calculation results while the US-DPC was charging at 30 kA and heater input of 100 W with the current leads cooled by cold helium vapor.

No. 20	Date 11/21	Time 16:58	US 30 kA Nuclear Heating 100W

Coil	Pancake		Flow g/s	P in atm	T in K	H in J/g	P out atm	T out K	H out J/g	Heat Load W
U S	# 1		9.75	6.034	4.616	12.98	5.093	4.891	13.81	8.1
	# 2		9.75	6.034	4.616	12.98	5.093	4.950	14.10	10.9
	# 3	Center	4.69	6.034	4.616	12.98	5.071	5.575	17.63	21.8
		Corner	5.60	6.034	4.616	12.98	5.040	5.594	17.76	26.8
	# 4	Corner	5.78	6.034	4.616	12.98	5.066	5.495	17.12	23.9
		Center	4.70	6.034	4.616	12.98	5.102	5.667	18.24	24.7
	# 5		11.58	6.034	4.507	12.57	5.094	4.566	12.40	-2.0
	# 6		11.58	6.034	4.507	12.57	5.094	4.735	13.10	6.1
C/L Cooling = Gas						Estimated Total Heat Load				120.4
U 1	# A		7.10	5.070	4.629	12.65	4.829	5.565	17.62	35.3
	# B		9.04	5.070	4.629	12.65	4.826	4.745	13.06	3.7
	# C		7.29	5.070	4.629	12.65	4.826	4.745	13.06	3.0
	# D		7.29	5.070	4.629	12.65	4.869	4.738	13.04	2.8
	# E		7.84	5.070	4.629	12.65	4.869	4.738	13.04	3.1
	# F		7.84	5.070	4.629	12.65	4.874	4.660	12.71	0.5
	# G		8.57	5.070	4.629	12.65	4.874	4.660	12.71	0.5
	# H		5.87	5.070	4.629	12.65	4.855	5.575	17.68	29.5
C/L Cooling = Gas						Estimated Total Heat Load				78.4
U 2	# A		8.45	5.015	4.630	12.63	4.928	6.146	22.60	84.2
	# B		3.12	5.015	4.630	12.63	4.858	4.725	12.98	1.1
	# C		6.75	5.015	4.630	12.63	4.858	4.725	12.98	2.4
	# D		6.75	5.015	4.630	12.63	4.835	4.677	12.76	0.9
	# E		6.65	5.015	4.630	12.63	4.835	4.677	12.76	0.9
	# F		6.65	5.015	4.630	12.63	4.833	4.677	12.76	0.9
	# G		4.05	5.015	4.630	12.63	4.833	4.677	12.76	0.5
	# H		7.02	5.015	4.630	12.63	4.874	5.747	18.93	44.2
C/L Cooling = Gas						Estimated Total Heat Load				135.1

Table 6.2 - (e) Coil heat load calculation results while the US-DPC, DPC-U1, and U2 were charging at 25 kA in series with the current leads cooled by liquid helium.

No. 31	Date 12/ 6	Time 0:22	U1+U2+US Series 25 kA

Coil	Pancake		Flow g/s	P in atm	T in K	H in J/g	P out atm	T out K	H out J/g	Heat Load W
U S	# 1		4.55	4.074	4.185	10.56	3.602	4.341	10.94	1.7
	# 2		4.55	4.074	4.185	10.56	3.602	4.130	10.17	-1.8
	# 3	Center	2.54	4.074	4.185	10.56	3.578	4.293	10.75	0.5
		Corner	2.61	4.074	4.185	10.56	3.598	4.062	9.93	-1.6
	# 4	Corner	2.77	4.074	4.185	10.56	3.602	4.109	10.09	-1.3
		Center	2.09	4.074	4.185	10.56	3.606	4.204	10.43	-0.3
	# 5		3.71	4.074	4.017	10.00	3.577	4.021	9.78	-0.8
	# 6		3.71	4.074	4.017	10.00	3.577	4.718	12.58	9.6
C/L Cooling = Liquid						Estimated Total Heat Load				6.0
U 1	# A		7.83	3.980	3.990	9.87	3.551	4.353	10.97	8.6
	# B		9.72	3.980	3.990	9.87	3.622	4.171	10.32	4.4
	# C		8.64	3.980	3.990	9.87	3.622	4.171	10.32	3.9
	# D		8.64	3.980	3.990	9.87	3.545	4.169	10.28	3.5
	# E		9.00	3.980	3.990	9.87	3.545	4.169	10.28	3.7
	# F		9.00	3.980	3.990	9.87	3.597	4.072	9.96	0.8
	# G		8.75	3.980	3.990	9.87	3.597	4.072	9.96	0.8
	# H		8.02	3.980	3.990	9.87	3.576	4.501	11.58	13.7
C/L Cooling = Liquid						Estimated Total Heat Load				39.4
U 2	# A		8.70	4.023	3.983	9.86	3.652	4.304	10.82	8.4
	# B		7.91	4.023	3.983	9.86	3.554	4.163	10.26	3.2
	# C		9.02	4.023	3.983	9.86	3.554	4.163	10.26	3.6
	# D		9.02	4.023	3.983	9.86	3.555	4.078	9.92	0.5
	# E		8.61	4.023	3.983	9.86	3.555	4.078	9.92	0.5
	# F		8.61	4.023	3.983	9.86	3.529	4.066	9.91	0.4
	# G		8.60	4.023	3.983	9.86	3.529	4.066	9.91	0.4
	# H		8.21	4.023	3.983	9.86	3.500	4.259	10.59	6.0
C/L Cooling = Liquid						Estimated Total Heat Load				23.0

The cooling of the current leads was performed so that cold helium vapor or liquid helium was supplied to the current leads by pressurizing the 20,000-liter liquid helium dewar through six parallel supply lines with a supplying pressure head of around 0.02 MPa. Unbalanced cooling flow distributions sometimes occurred in such operation. In practice, according to Table 6.2, the heat loads for the pancake No. 1 and No. 6 were 2.6. to 8.1 W and 6.1 to 66 W with cold helium vapor cooling and -34.6 to 12.2 W and -30.5 to 9.6 W with liquid helium cooling. Note that the negative heat load means that the pancake heat should conduct to the current lead. Heat loads for pancakes No. 1 and No. 6 account for almost all of the coil heat load.

In the stand-by mode, where the total cold helium vapor supplied to each current lead was approximately 0.2 g/s, the total heat load of the US-DPC was approximately 66 watts as listed in Table 6.2 (a). In the US-DPC 30 kA single-coil charge, where a total of 4 to 7 g/s liquid helium was supplied to the three sets of current leads, the total heat load of the US-DPC was approximately 42 watts as listed in Table 6.2 (c).

6.4 Pressure drop performance

6.4.1 Pressure drop performance measurements

During cooldown the Reynolds number of the helium flowing through the coil changed from a few hundreds to a few thousands, and the pressure drop as a function of mass flow was observed on pancake No. 1 of the US-DPC. The data were arranged as friction factor vs. Reynolds number to characterize the coil pressure drop performance.

6.4.2 Data arrangement

1) Reynolds number

The Reynolds number (Re) is calculated from the following formula:

$$\mathrm{Re} = \frac{\dot{m} D_h}{\mu\, A_h} \qquad (6.1)$$

where $\dot{m}$ is the mass flow rate (g/s) of the pancake, D_h is the hydraulic diameter (cm) of the pancake, μ is the helium viscosity (g/cm-s), and A_h is the helium cross-section (cm^2) of the pancake.

2) Friction factor (Darcy's friction factor)

The Friction factor (f) is calculated from the following formula:

$$f = \frac{2 \rho g D_h A_h^2 \Delta P}{L \dot{m}^2} \qquad (6.2)$$

where g is gravity acceleration (981 cm/s^2), ρ is helium density (g/cm^2), ΔP is pressure drop through the pancake (gf/cm^2), and L is the length of a flow channel (cm).

3) Helium density and viscosity

The helium density and viscosity were calculated by using the average temperature and pressure of the pancake at the inlet and outlet:

$$T_{av} = 0.5\ (T_i + T_o), \tag{6.3}$$

$$P_{av} = 0.5\ (P_i + P_o) \tag{6.4}$$

where T_{av} is the average temperature (K), T_i is the helium inlet temperature (K) of the pancake, T_o is the outlet temperature of the pancake, and P_{av}, P_i and P_o refer to average, inlet, and outlet pressure (atm), respectively.

4) Helium cross-section (A_h)

There are two flow paths in a coil pancake: the main-flow channel for cable-cooling and the sub-flow channel for conductor cooling, as shown in Figure 6.7. The helium cross section of the main-flow channel is 0.743 cm^2 and that of the sub-flow channel is 0.536 cm^2.

5) Hydraulic diameter (D_h)

The hydraulic diameter is defined as follows:

$$D_h = \frac{4A_h}{Pe} \tag{6.5}$$

where Pe is wetted perimeter. The wetted perimeter for the main-flow channel is 61.44 cm, and 11.76 cm for the sub-flow channel.

The hydraulic diameter is estimated as a composite hydraulic diameter for both flow channels based on the parallel flow circuit as shown in Figure 6.7. In the laminar flow regime, the pressure drop for each flow channel is expressed as follows:

$$\Delta P = \frac{C\dot{m}_1}{A_{h1}D_{h1}^2} \tag{6.6}$$

$$\Delta P = \frac{C\dot{m}_2}{A_{h2}D_{h2}^2} \tag{6.7}$$

where C is a constant, the subscript 1 refers to the main flow channel, and the subscript 2 refers to the sub flow channel. The total mass flow $\dot{m}$ is expressed as $\dot{m} = \dot{m}_1 + \dot{m}_2$. Using these relationships, the pressure drop as a function of the total mass flow is expressed as:

$$\Delta P = \frac{C\dot{m}}{A_{h1}D_{h1}^2 + A_{h2}D_{h2}^2} \tag{6.8}$$

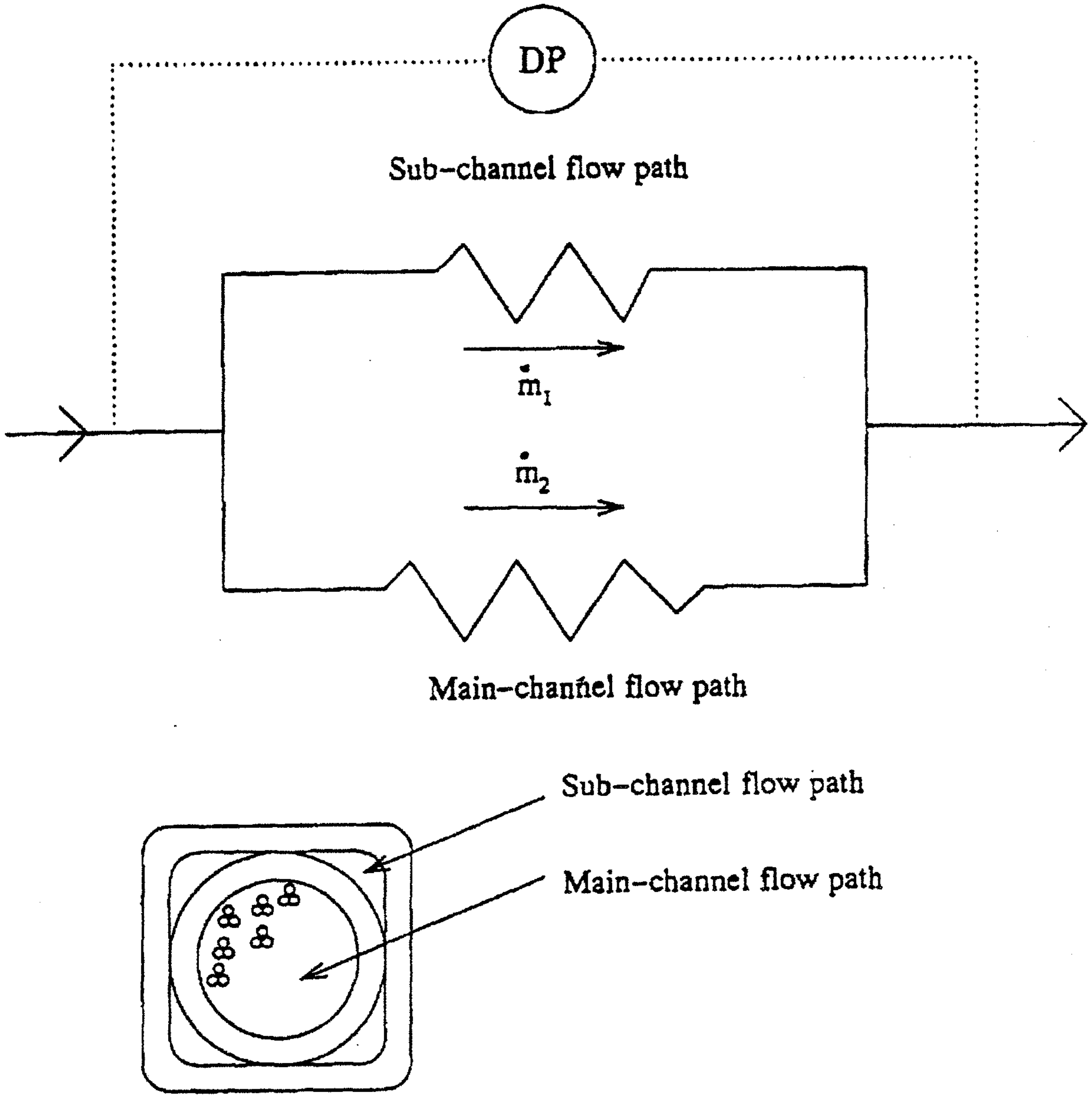


Figure 6.7 - The model used to estimate the composite hydraulic diameter for the sub-channel flow and the main-channel flow of the conductor.

The pressure drop is expressed as a function of the composite hydraulic diameter (D_h) and the helium cross section (A_h) as follows:

$$\Delta P = \frac{C\dot{m}}{A_h D_h^2} \tag{6.9}$$

Thus, the composite hydraulic diameter is:

$$D_h = \sqrt{\frac{A_{h1}D_{h1}^2 + A_{h2}D_{h2}^2}{A_h}} \tag{6.10}$$

The composite hydraulic diameter is determined to be 0.1236 cm.

6.4.3 Pressure drop performance results

Using the values as defined above, the friction factor as a function of Reynolds number is shown in Figure 6.8. In this figure the Haugen-Poiseuille relation for the laminar flow regime of a smooth tube is also shown. The empirical relation[1], which modifies the formula of Plandtl-Karman as:

$$\sqrt{\frac{1}{f}} = 0.87 \ \ln (\mathrm{Re}\sqrt{f}) + A \tag{6.11}$$

is also shown in Figure 6.8. Here, A is selected to be 3.0 to fit the data.

The data show the friction factor to be higher than the friction factor determined by the Haugen-Poiseuille and Blasius relations. The transition region from laminar flow to turbulent flow could not be defined easily. The empirical relation shows good agreement for the data up to Reynolds numbers of a few thousand.

Another estimation of the composite hydraulic diameter is performed by attempting to fit in the data to the Haugen-Poiseuille relation at the region of the low Reynolds number, the definition of the composite hydraulic diameter for this analysis is:

$$D_h = \frac{A_{h1}D_{h1} + A_{h2}D_{h2}}{A_h} \tag{6.12}$$

where it is assumed that A_hD_h is the key parameter for determination of the relationship between the pressure drop and mass flow rate through the pancake. The arithmetic average of $A_{h1}D_{h1} + A_{h2}D_{h2}$ is taken into account for the parallel flow circuit, and D is calculated to be 0.1045 cm. The pressure drop performance plotted as the friction factor versus Reynolds number is shown in Figure 6.9.

In Figure 6.9, the relations of Haugen-Poiseuille, Blasius, and the empirical formula, where A was chosen as 2.7 to fit in the data, are also plotted. The data are close to the Haugen-Poiseuille relation to Reynolds numbers of a few hundreds.

References

1. E. Tada, et al., "Thermal Performance Results of the Nb-Ti Demo Poloidal Coils (DPC-U1, U2)", Proc. MT-11 (1989) p. 830.

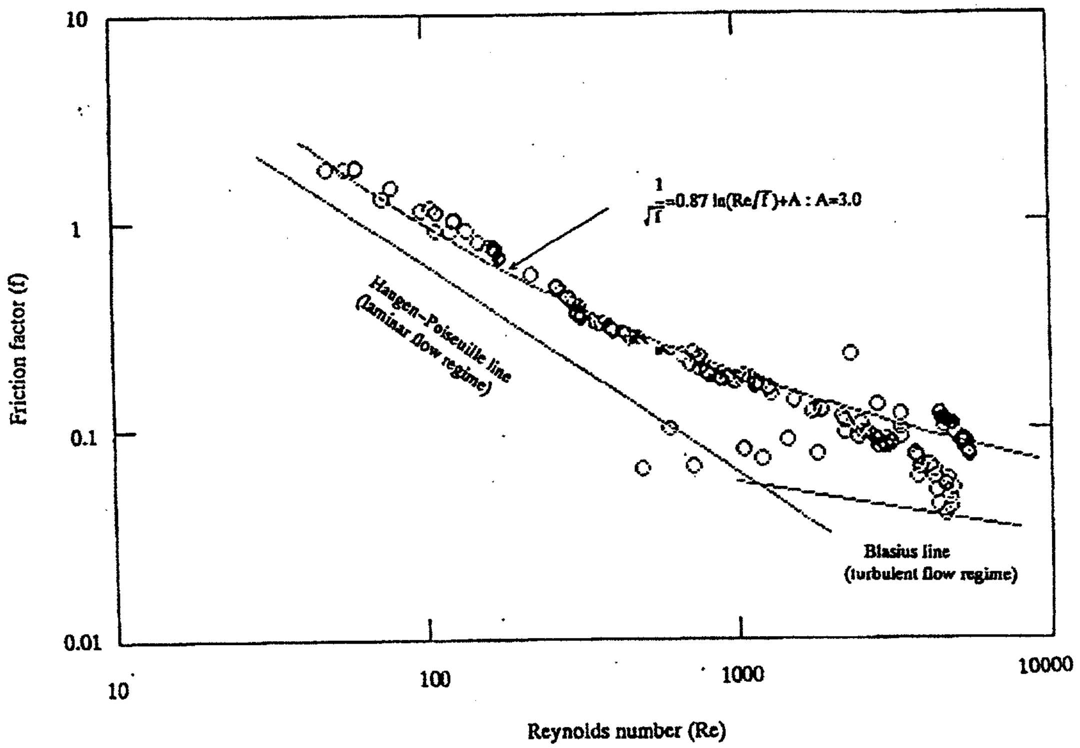


Figure 6.8 - Pressure drop performance of pancake no.1 using an estimated hydraulic diameter of 0.1236 cm.

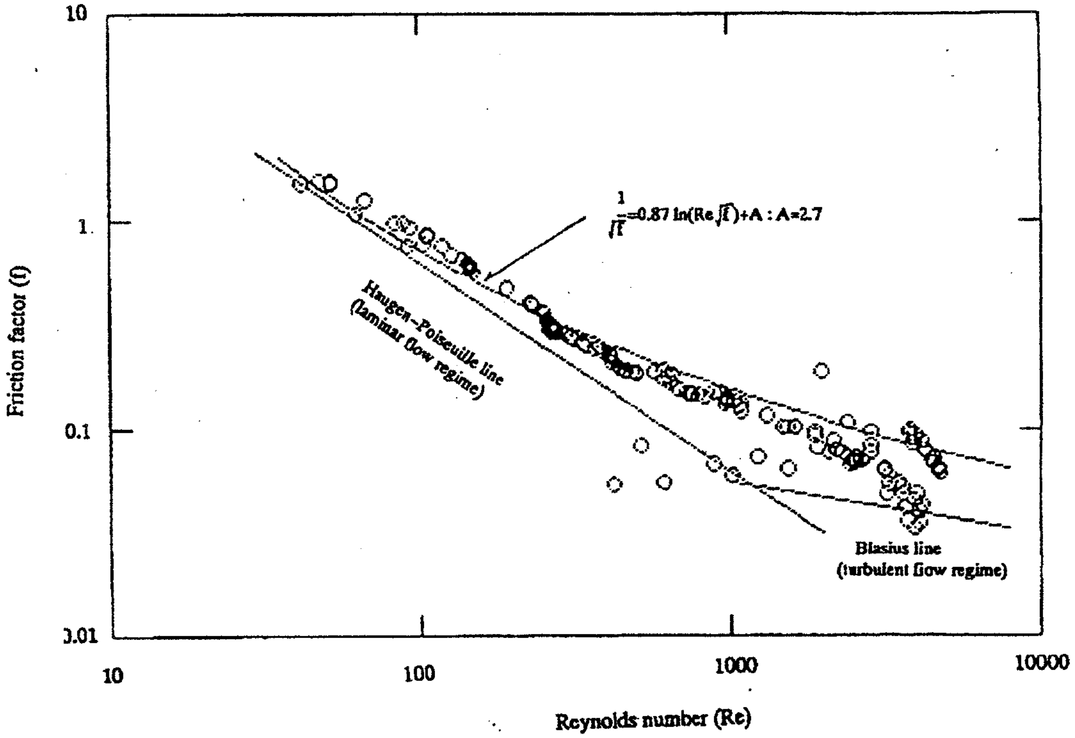


Figure 6.9 - Pressure drop performance of pancake no.1 using an estimated hydraulic diameter of 0.1045 cm.

7. Single-coil DC test results

Tests of the US-DPC alone established that the coil was leak tight (1-2 μTorr vacuum) under moderate mechanical loads, the cryogenic system was working properly, the lap joint resistances were low (≤ 0.5 nΩ at 30 kA with 2.2 T at lap joints), the protection system was working, and there was no significant damage to or degradation of the Nb_3Sn cable.

7.1 Examination of voltage traces of runs 13 - 25 and 32 - 38

Most of the data for dc runs is contained as folding strip chart records and some as digital memory records. The x-t traces of runs 13 - 25 and 32 - 38 were investigated with concentration on the crossover turns A, B and C. The investigation attempted to answer questions such as the following. Was there any evidence of normal zones not observed during the experiment? Since coil quenches originated mostly in the crossover of double pancake C, was there more voltage noise on the crossover of C than on A or B? If so, was it repeatable? Was it dependent on ramp rate?

The investigation considered folding strip charts designated XT-02: nos. 1, 2, 3 and 3' and digital memory data where available. Crossover-turn voltages A, B and C and coil current were considered. The study examined upward ramps and flattops; downward ramps and flattops were not examined. The observations were found to be:

1) Noise on voltage traces was not reproducible from run to run (see Fig. 7.1). It did not happen at the same currents or ramp rates. There was a small amount of noise at zero current before most runs.

2) Noise of significant amplitude on the three crossover turns was simultaneous and geometrically similar. There was no occurrence of isolated signals of significant amplitude on A, B or C. "Significant amplitude" means voltage spikes greater than about 10 μV (note that critical voltage was defined as 3.30 m x 10 μV/m = 33 μV). See Fig. 7.2.

3) The ratio of inductive voltage signals A:B:C during ramps was identical to the ratio of significant-amplitude noise signals A:B:C in all cases examined. The ratio was approximately 1 : 1.33 : 1.52. (Note that resistive (?) voltages altered the ratios slightly at higher currents by adding or subtracting resistive signals to the inductive signals.)

4) The noise was not periodic. It was not sinusoidal. It appeared as sequences of single spikes, sometimes closely spaced and sometimes not. There were both noisy (run 23) and noise-free (run 24) runs.

5) There were apparently resistive voltages at the current flattops (current transfer? electronics? thermoelectric?), which were fairly consistent and reproducible in all runs examined. Crossover A developed negative voltages at nonzero currents, B developed positive voltages, and C developed predominantly negative voltages. As an example, measurements from runs 18 and 20 are listed in Table 7.1 (≈ ± 3 μV).

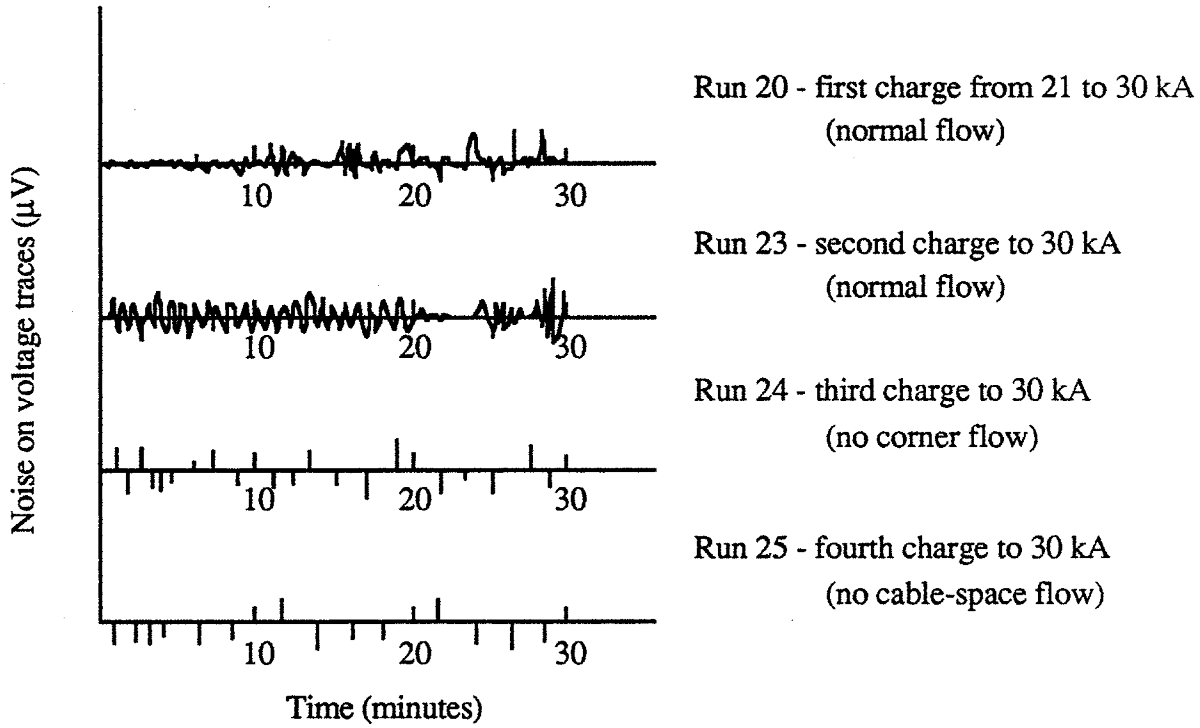


Figure 7.1 - Illustration of noise voltages on runs 20, 23, 24 and 25 for upward ramps and flattops to 30 kA. The four sketches show that the noise was not reproducible from run to run.

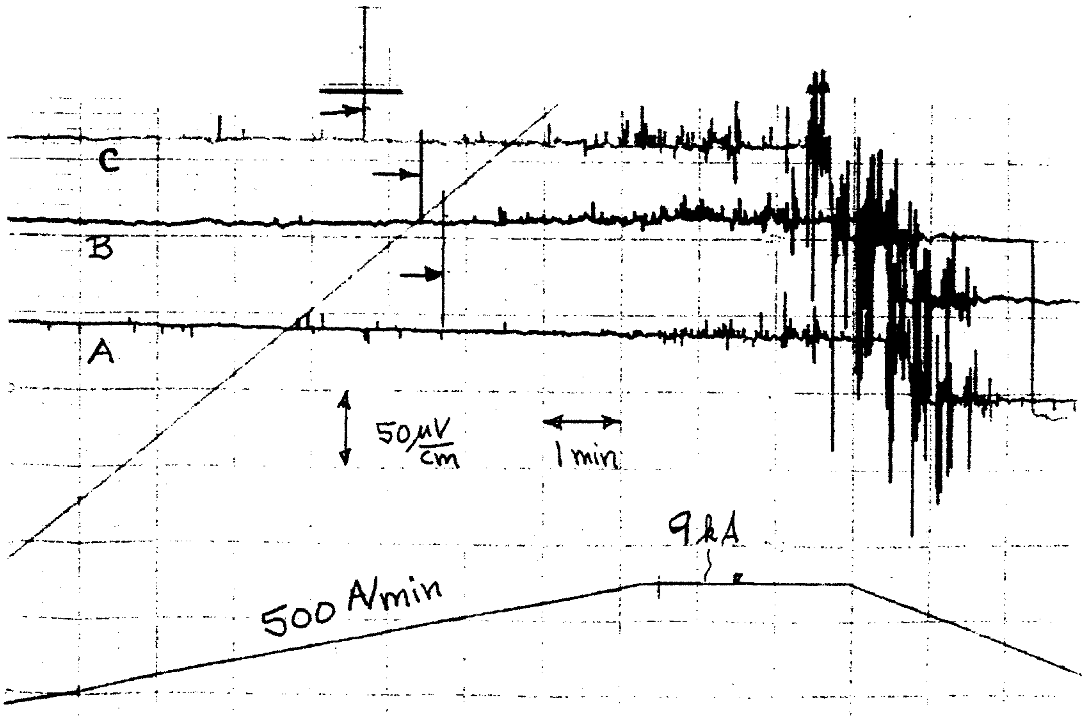


Figure 7.2 - Noise voltages for run 13 on crossovers A, B and C. The signals were simultaneous and in fixed proportion to each other, indicative of inductive voltages. The offsets in time are due to the staggered placement of the chart recorder pens. The vertical sensitivity is 50 µV/cm and the horizontal sensitivity is 1 min/cm.

Table 7.1 - Voltages at current flattops (di/dt = 0) for runs 18 and 20.

Run 18

	A	B	C
Current	V (V/I)	V (V/I)	V (V/I)
9 kA	-6 μV (-0.7 nΩ)	+ 12 μV (1.3 nΩ)	-5 μV (-0.6 nΩ)
15 kA	-18 μV (-1.2 nΩ)	+ 19 μV (1.3 nΩ)	-12 μV (-0.8 nΩ)
18 kA	-22 μV (-1.2 nΩ)	+ 20 μV (1.1 nΩ)	-16 μV (-0.9 nΩ)
21 kA	-26 μV (-1.2 nΩ)	+ 28 μV (1.3 nΩ)	-18 μV (-0.9 nΩ)

Run 20

	A	B	C
Current	V (V/I)	V (V/I)	V (V/I)
9 kA	-10 μV (-1.1 nΩ)	+ 10 μV (1.1 nΩ)	+9 μV (1 nΩ)
15 kA	-18 μV (-1.2 nΩ)	+ 18 μV (1.2 nΩ)	+5 μV (0.3 nΩ)
18 kA	-20 μV (-1.1 nΩ)	+ 22 μV (1.2 nΩ)	- 5 μV (-0.3 nΩ)
21 kA	-22 μV (-1.0 nΩ)	+ 30 μV (1.4 nΩ)	- 9 μV (-0.4 nΩ)
24 kA	-27 μV (-1.1 nΩ)	+ 30 μV (1.4 nΩ)	- 8 μV (-0.3 nΩ)
27 kA	-32 μV (-1.2 nΩ)	+ 41 μV (1.5 nΩ)	- 9 μV (-0.3 nΩ)
28.2 kA	shorted VT	+ 40 μV (1.4 nΩ)	- 8 μV (-0.3 nΩ)

6) During the intermediate ramps with the dc power supply, there were either significant resistive, as well as inductive, voltages on the crossover of B or the inductive voltage increased linearly in time (ramp rates from 5 kA/min to 30 kA/min - runs 32 to 38). See Figure 7.3 and Table 7.2.

7) There were insignificant voltages on the crossovers of A and C during the intermediate ramps, which are difficult to resolve. The A voltage was negative and the C voltage positive; both were roughly 20 μV at the end of the ramp (30 kA). See Figure 7.3.

8) During the intermediate ramps with the dc power supply, the inductance of crossover B appeared to decrease by roughly 2 - 4 % going from 5 kA/min to 30 kA/min. See Table 7.2.

9) There were isolated small-amplitude noise spikes on the crossover of A which were not evident on either B or C. They were predominantly of negative polarity and of roughly 5 - 10 μV amplitude.

10) The time stability of the instrumentation amplifiers appeared to be excellent. The drift was less than approximately 1 - 2 μV at sensitivities of 50 μV/cm.

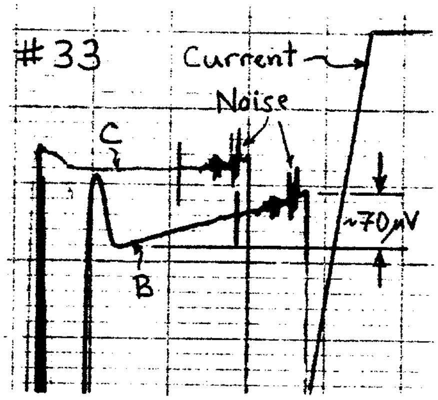


Figure 7.3 -Comparison of induced voltages in crossovers B and C during a ramp to 30 kA at 10 kA/min (run 33). The resistive voltage component on B can be modeled as a constant resistance of roughly 3 nΩ or a linear increase in inductance with current. Typical geometrically-similar noise signals can be seen also on B and C.

Table 7.2 - Apparent inductance of crossover B at the beginning and end of intermediate ramps to 30 kA (runs 32 to 38). The voltage V_i denotes voltage at the beginning of the fast ramp, which was at a current of approximately 1 kA, not 0 kA, since an initially slow ramp was required to lessen the inductive signal due to the Incoloy magnetization. The voltage V_f denotes voltage at the end of the fast ramp.

Run	di/dt	di/dt	V_i	V_f	$V_i$dt/di	$V_f$dt/di
32	5kA/min	83.3 A/s	545 μV	555μV	6.543 μH	6.660 μH
33	10	166.7	1090	1110	6.540	6.660
34	15	250	1600	1650	6.400	6.660
35	20	333.3	2125	2175	6.375	6.525
36	25	416.7	2650	2725	6.360	6.540
37	30	500	3175	3250	6.350	6.500
38	30	500	3150	3250	6.300	6.500

7.1.1 Nature of noise signals

The noise signals of significant amplitude were inductive in nature. That is, flux from the noise events linked the three pick-up loops of the crossover-turn voltage taps in exactly the same way that flux from the transport current linked the loops. This implies that the noise source was common to the three crossovers and may have been due to the power supply, because it is difficult to see how a local perturbation in current could yield signals that were exactly proportional to the ramp-up signals. (Local events would generate bigger voltage signals in the loops that were closer and smaller signals in the loops that were further from the source.) The higher noise on C was due to a slightly larger Faraday's law pick-up loop relative to A and B; the area ratios of the loops A:B:C is 1 : 1.33 : 1.52.

The isolated small-amplitude noise spikes on the crossover of A were not evident on either B or, more importantly, on C. One of the goals of this study was to see if there were any special events on C. This study found nothing special or unusual in the behavior of C relative to A and B.

7.1.2 Additional resistive/inductive voltages

The observed voltages on the crossovers during flattops can be explained by a current transfer mechanism, which is a function of the location of voltage taps relative to where the transfer takes place. This is the only way to rationalize the occurrence of negative-resistance voltage signals, if it is assumed that the instrumentation amplifiers were stable in time and that thermoelectric effects were not present.

The growing voltage on crossover B during the intermediate ramps (runs 32 - 38) implies either a fixed resistance above the "current transfer" value, present only during the ramps, or an increase in inductance during the ramps. An increase in inductance could have at least two causes. They are either a redistribution of current in the cable (current moves radially inward in strands) or an increase in the area enclosed by the crossover turn due to Lorentz forces. The observed linear change in inductance is more likely due to a current redistribution than an area change, because the crossover radius will grow linearly with applied force; applied force is proportional to current squared, and loop area is proportional to radius squared. This implies that the inductance would not vary linearly, rather it would vary roughly as the sum of two terms, the first with current squared and the second with current raised to the fourth power.

7.2 Current-sharing temperature measurements

The coil was first charged to a given current and then the inlet helium temperature was slowly increased by using two resistive heaters shown as a main heater and a sub-heater in Figure 5.9. The temperature was adjusted by the input power of the main heater (100 W to 400 W). The sub-heater power was always 70 W which made the A and B double pancakes warmer than C. The helium temperature was continuously raised until resistive voltage was observed on the crossover turn (innermost turn). The crossover turn voltage of the center double pancake (B) rose first, followed by that of coil A. The temperature increment near the critical point was about 0.3 K per minute.

Figure 7.5 shows crossover turn voltages of B and C as a function of inlet helium temperature. As seen in this figure, the crossover voltage of B increased gradually with increasing temperature. On the other hand the voltages of A and C decreased. Similar behavior of the crossover voltages was observed in critical current measurements which will be shown in the next section. The gradual slope of crossover voltage was separated by an extrapolation of a straight-line fit in order to read current-sharing temperature and critical current.

Table 7.3 shows the measurement results of current-sharing temperatures. Data were obtained at an electric field criterion of 10 μV/m.

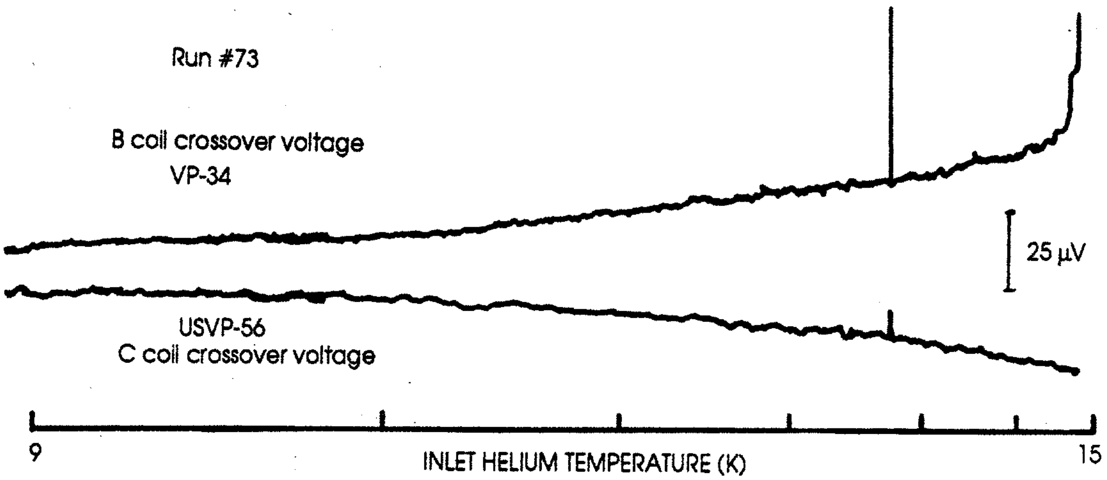


Figure 7.5 - Reproduced crossover turn voltage traces of double pancakes B and C as a function of inlet helium temperature measured by carbon-glass sensor USTC01 (Run #73).

Table 7.3 - Results of current-sharing temperature measurements.

Run	Current	Field	Temperature
73	5.0 kA	0.94 T	14.8 K
28	10.0	1.9	13.6
29	15.0	2.8	12.5
30	20.1	3.8	11.6
43	25.1	4.7	10.5
44	30.0	5.7	9.3

7.3 Critical-current measurements

In critical current measurements, temperature was first raised in the same method as that of the current-sharing temperature measurements. Temperature was stabilized at a given value, and then the coil was charged until resistive voltage was observed on the crossover turn of the center double pancake as seen in Figure 7.6. Part (a) of this figure shows crossover turn voltages of B and C and inlet helium temperature as a function of current. The crossover voltage of double pancake B increased gradually with increasing current, and the voltages of A and C decreased as seen in the current-sharing temperature measurements. However, the voltage of the entire pancake (75 m), including a half of a crossover turn, did not develop a significant slope as shown in Figure 7.6 (b).

Table 7.4 shows the measurement results of critical currents at an electric field criterion of 10 μV/m. The current ramp rates were 0.2 kA/min (Run #45), 0.5 kA/min (Run #46), and 1 kA/min (Run #72). In this table the shape-exponent parameter n is also shown, which has been defined as follows,

$$V = V_0(I/I_0)^n$$

where I_0 is a current at a reference criterion voltage V_0. In this analysis, the gradual slope of the crossover voltage was separated from the measured voltage by a straight-line fit.

Figure 7.7 summarizes the results of critical current and current-sharing temperature measurements. Solid triangles and circles show critical current and current-sharing temperature results, respectively. Two other data sets, obtained from single-strand tests, are also plotted in this figure. The open squares show critical temperatures estimated from the temperature dependence of critical currents of single wires similar to US-DPC wire measured at the University of Wisconsin[1]. Open circles in figure 7.7 were obtained from an interpolation of the zero-current critical temperature $T_c^*(B)$ obtained at Oxford University for a bronze-matrix Nb_3Sn wire[2] and the critical currents of US-DPC wire measured at MIT[3].

As seen in Figure 7.7, the performance of the US-DPC was slightly better than the predictions from single wire data. This could be explained by a lessening of the uniaxial strain effect created by mechanical coupling of the superconducting cable to the low thermal-coefficient-of-expansion Incoloy 908 conduits[4].

The strain effect has been evaluated by using a critical current equation developed by Summers et al[5]. They obtained the following critical current formula as a function of field B, temperature T and uniaxial intrinsic strain ε, on the basis of previous work of Hampshire et al[6] for temperature dependence, and Ekin[7] for strain dependence.

$$I_c(B,T,\varepsilon) = C(\varepsilon)\,\{B_{c2}(T,\varepsilon)\}^{-1/2}(1-t^2)^2 b^{-1/2}(1-b)^2 \qquad \text{(A)} \qquad (7.1)$$

where

$$C(\varepsilon) = C_0(1-a|\varepsilon|^u)^{1/2} \qquad (AT^{1/2})$$

$$B_{c2}(T,\varepsilon) = B_{c20}(\varepsilon)(1-t^2)\{1 - 0.31\, t^2 (1 - 1.77 \ln(t))\} \qquad (T)$$

$$B_{c20}(\varepsilon) = B_{c20m}(1-a|\varepsilon|^u) \qquad (T)$$

$t = T/T_{c0}(\varepsilon)$

$b = B/B_{c2}(T,\varepsilon)$

$T_{c0}(\varepsilon) = T_{c0m}\,(1-a\,|\varepsilon|^{u})^{1/w}$ (K)

$a = 900$ for $\varepsilon < 0$, 1200 for $\varepsilon > 0$

$u = 1.7$

$w = 3$

B_{c20m} = Maximum (strain-free) upper critical field (T)

T_{c0m} = Maximum zero-field critical temperature (K)

C_0 = Coefficient independent of field, temperature, and strain ($AT^{1/2}$)

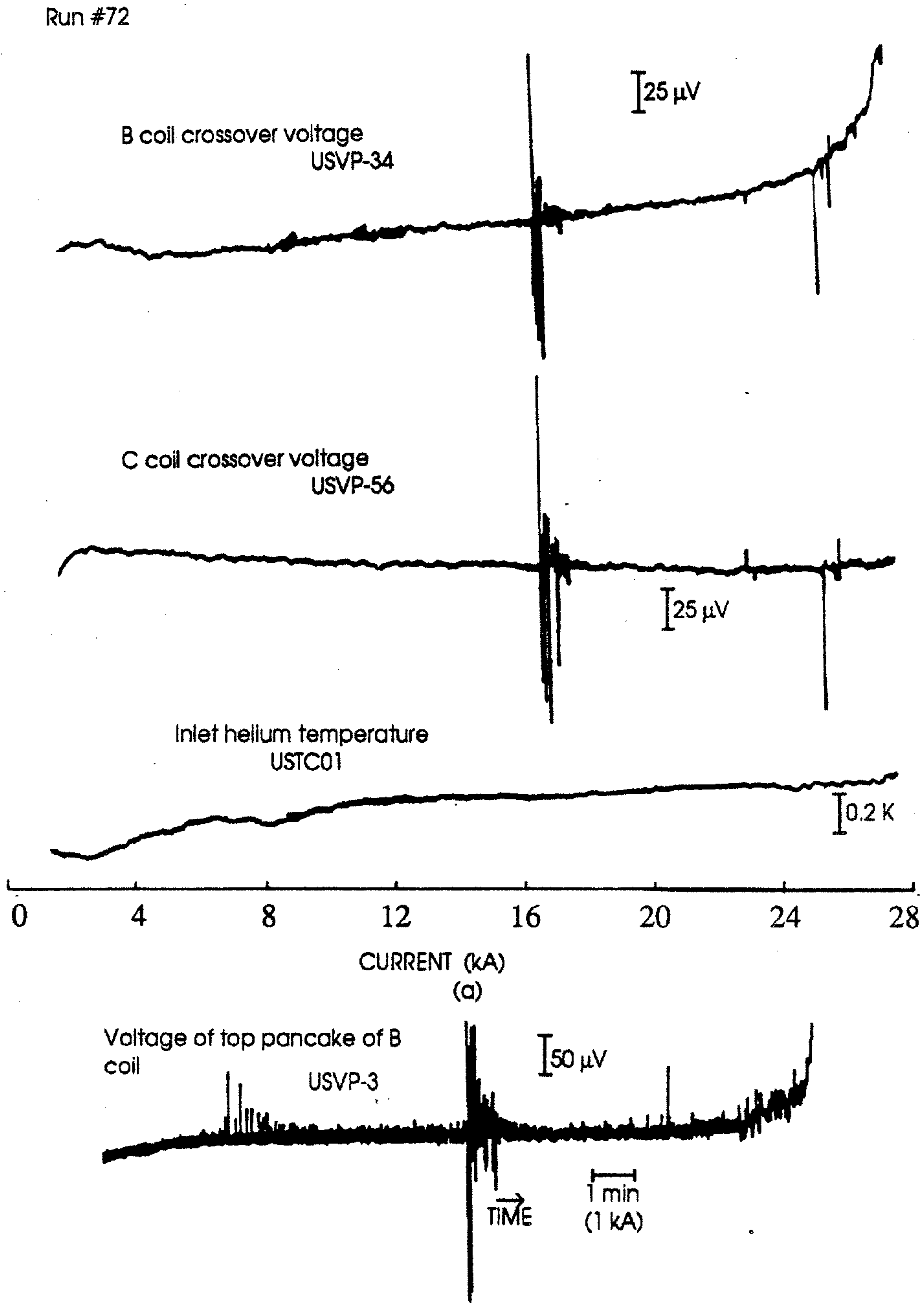
ε = Uniaxial strain

The last four items are input parameters for curve fits. Three parameters (B_{c20m}, T_{c0m}, and C_0) are related to the material properties of the superconductor. The strain ε relates to sample fabrication or handling and operating conditions (temperature, Lorentz force).

When $B_{c20m} = 27.5$ T, $T_{c0m} = 16$ K, and $C_0 = 8800\ AT^{1/2}$ were selected for curve fits of single-wire and US-DPC coil data, the resulting fits to Equation 7.1 were made by adjusting strain values only[4]. The US-DPC coil showed a strain of -0.1%. Single-strand samples on a stainless steel barrels tested at MIT showed intrinsic uniaxial compressive strains of about -0.36%. The two solid lines in figure 7.7 are calculated from Equation 7.1 with intrinsic strains ε = -0.10% and -0.46%. The critical current data at temperatures between 2.5 K and 11 K measured at the University of Wisconsin were confirmed to fit Equation 7.1 with ε = -0.46% with B_{c20m}, T_{c0m}, and C_0 the same as above. Experimental strain data of the US-DPC wire measured by Ekin and Bray[8] have been shown to agree fairly well with the calculated data obtained from Equation 7.1 using the above selected parameters.

Table 7.4 - Results of critical-current measurements.

Run	Temperature	Current	Field	n
45	11.8 K	19.02 kA	3.6 T	35
46	11.0	22.94	4.3	27
72	10.2	26.65	5.0	20



(b)

Figure 7.6 - Reproduced traces of (a) crossover turn voltages of double pancakes B and C, and inlet helium temperature as a function of charge current, and (b) entire pancake voltage of top pancake of double pancake B (Run #72).

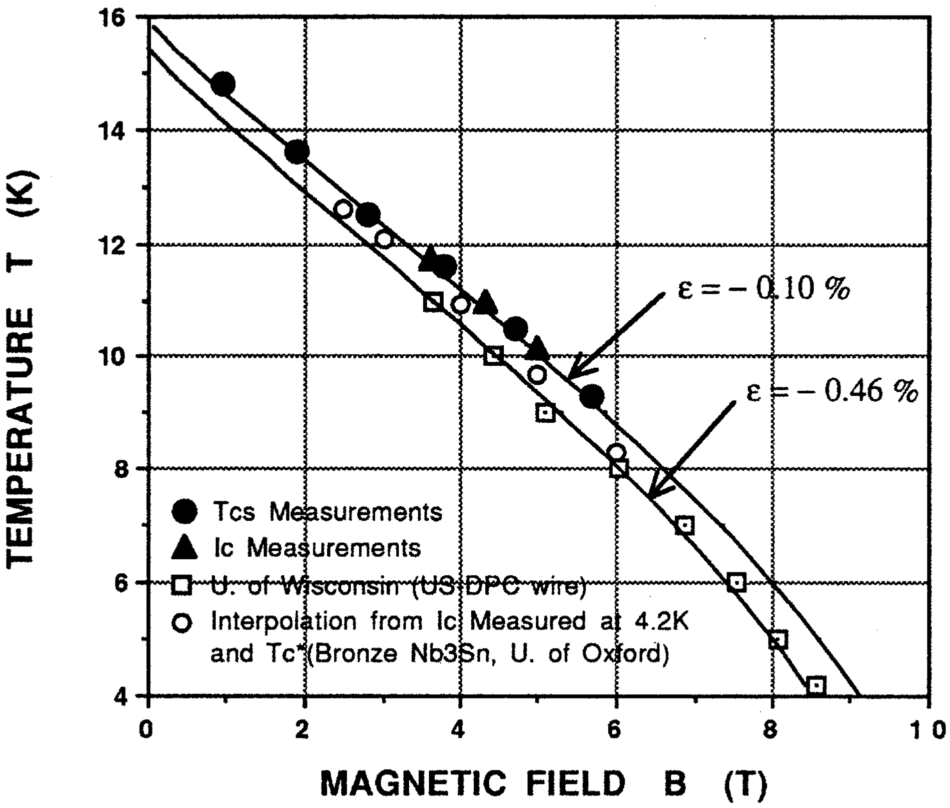


Figure 7.7 - Test results of critical current and current-sharing temperature for the US-DPC coil with expectations obtained from single-strand data. The solid lines were obtained from Eq. 7.1 with intrinsic strains ε = -0.10% and -0.46% using B_{c20m}= 27.5 T, T_{c0m}= 16 K, and C_0 = 8800 $AT^{1/2}$.

7.4 Simulated nuclear heating and AC loss calibration

In order to investigate the performance of the US-DPC under nuclear heating loads, cable heating wires were installed in double pancakes A and B (see Figure 5.2). Runs 39 and 40 are runs in which the cable heater of B was energized, and the following two sections provide analysis of these runs. Section 7.4.1 presents quantitatively the areas of stable operation maintained under heat loads from the cable heaters, and section 7.4.2 calibrates the AC loss measurement technique by using the cable heaters to provide a known energy input into double pancake B.

7.4.1 Stability of US-DPC under nuclear heat loads

The 150 m length coaxial cable heater of double pancake B was energized in runs 39 and 40 to deposit a known power per unit length in the conductor during steady-state dc operation. Inlet flow conditions to the entire coil were set at an absolute pressure of 7.1 atmospheres, a temperature of 4.6 K and a mass flow of approximately 60 g/s. Current-versus-time profiles that indicate when the heater was energized are given in Figure 7.8.

In Run 39, the US-DPC was charged at 10 kA/min to 20 kA and the heater charged at a current of 0.78 A to deposit a power of approximately 84.2 watts(≈ 0.55 w/m) in the cable based on a measured heater resistance of 135 Ω at 4.5 K. The heater was then turned off and the current ramped at 10 kA/min to 30 kA where the heater was turned on again at 82.1 w. The coil was completely stable with no observed resistive voltages, but with observed flow choking at the helium inlet of double pancake B.

In run 40, the US-DPC was charged at 10 kA/min to 30 kA and the heater energized to approximately 100, 152 and 208 w respectively (maximum power was limited by flow choking at the B helium inlet). No normal voltages were observed. After the heater was turned off, the coil was dumped successfully from 30 kA into the 49.3 mΩ dump resistor. This was the second full-current dump of the US-DPC.

7.4.2 Calibration of mass flow in AC loss measurements

This section presents an investigation of nuclear heating run 40 for the purpose of estimating the total mass flow in double pancake B. The method uses the known heater power as a basis of estimating a total outlet flow that would give the observed temperature rises (changes in enthalpy) in the four outlets of B. The goal of this comparison of "estimated flow from temperature rises" to "measured flow by meters" is to calibrate the AC loss measurements given in later sections and to estimate their level of accuracy.

Assumptions

1) During the heat-pulse flattop, thermal equilibrium was established (steady state, steady flow process).
2) The outlet pressures were constant and unchanged by the heating pulse.
3) Heater power during the pulse flattop was constant and equal to 151.7 watts.
4) The outlet temperature measurements via the CGR's were accurate.
5) The mass flow - pressure drop equations provided by JAERI are accurate in the range of operation considered.
6) The mass flows in pancakes 1 and 2 were equal to each other; the mass flows in pancakes 5 and 6 were equal to each other.
7) Mass flow may be estimated by using the average enthalpy difference determined from the four outlets of double pancake B.

Results

Based on the difference in outlet temperatures before and during the heating interval, the estimated total mass flow through coil B for run 40, DM-48 was 17.60 g/s. The measured total mass flow from USMC-04, 05, 06, 07, using the JAERI pressure drop versus mass flow equations, was 17.12 g/s. The ratio of "estimated by temperature rises" to "measured by flow meters" is 17.60/17.12 = 1.028.

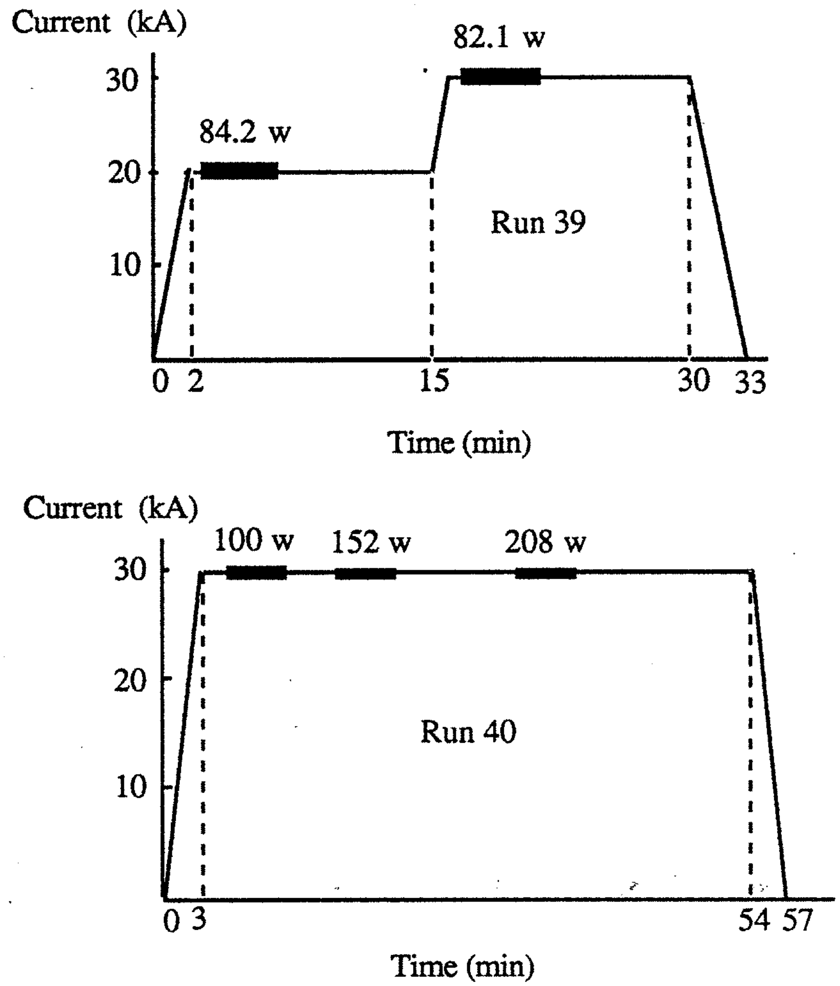


Figure 7.8 - Current-versus-time profiles for single-coil dc nuclear-heating runs 39 and 40. The coil was charged and discharged at 10 kA/min. Flat top times are approximate. The heater was energized 3 to 4 minutes at the power levels shown. No normal voltages were observed at any time.

Analysis

The method of analysis is outlined here. The experiment was designated run 40, DM 48. The heater was in the center of double pancake B; it had a resistance of 135 Ω at 4.5 K. The heat pulse was trapezoidal with approximately a 20 s rise time, a 200 s flattop, and a 20 s fall time. The heater power during the 200 s flat top was 151.7 w. The temperatures before and during the pulse are listed in Table 7.5.

The pressures before and during the pulse are assumed equal. This assumption is based on an examination of the XT traces of the pressure transducers in which the pressure rise during the pulse was observed to be no more than approximately 3 - 5 % (see XT-3 records). Table 7.6 lists the appropriate helium enthalpies.

Table 7.5 - Outlet temperatures measured by calibrated carbon glass resistors before and during the heat pulse by the cable heater. Precision is ≈ ± 0.75 mK.

Outlet Location	Sensor	T_{during}	T_{before}	$\Delta T = T_{during} - T_{before}$
pancake 1	TC03	4.928 K	4.898 K	0.030 K
pancake 2	04	5.025	4.902	0.123
pancake 3 - cable	05	5.990	4.690	1.300
pancake 3 - corner	06	6.000	4.730	1.270
pancake 4 - corner	07	5.880	4.670	1.210
pancake 4 - cable	08	6.100	4.750	1.350
pancake 5	09	4.632	4.527	0.105
pancake 6	10	4.784	4.760	0.024

Table 7.6 - Outlet temperatures, absolute pressures and enthalpies for run 40, DM 48.

Outlet Location	Pressure	T_{during}	h_{during}	T_{before}	h_{before}
pancake 1	5.17 atm	4.928 K	14.05 J/g	4.898 K	13.92 J/g
pancake 2	5.17	5.025	14.50	4.902	13.94
pancake 3 - cable	5.15	5.990	20.76	4.690	13.00
pancake 3 - corner	5.16	6.000	20.83	4.730	13.18
pancake 4 - corner	5.13	5.880	19.97	4.670	12.91
pancake 4 - cable	5.13	6.100	21.99	4.750	13.26
pancake 5	5.12	4.632	12.74	4.527	12.28
pancake 6	5.12	4.784	13.41	4.760	13.30

Parasitic losses

The parasitic heat losses to A and C were calculated assuming mass flows in these double pancakes to be as measured by inlet meters MC01 for A and MC03 for C. The equations of the meters were given by JAERI and are thought to be accurate based on calibrations of at least one meter with water. They are:

USMC01 and 02: $\dot{m} = 2.36\ (\rho\ \Delta P)^{0.5}$
USMC03: $\dot{m} = 4.86\ (\rho\ \Delta P)^{0.5}$
where ρ = helium density [g/cc]
ΔP = pressure drop across orifice [mm Aq]

The unit "mm Aq" stands for millimeters of water, where 1 atm = 10,334 mm Aq at 4 C. The densities and pressure drops for calculations of mass flow in A and C are listed in Table 7.7.

Table 7.7 - Supercritical helium absolute pressures, temperatures, densities and pressure drops for A and C inlets.

Location	Pressure	Temperature	Density	Pressure Drop
	PT01	TC01	NBS 631	MC01
A	6.08 atm	4.616 K	0.1388 g/cc	375 mm Aq
	PT02	TC02	NBS 631	MC03
C	5.96	4.506	0.1402	278

The calculated mass flows into A and C are thus

$\dot{m}$ (A) = 17.0 g/s $\dot{m}$ (C) = 30.0 g/s

The parasitic losses from B to A and C during the nuclear heating pulse can be estimated using these flows. They are

Loss to A $P_A \approx 0.5\,\dot{m}\,[(h_{during} - h_{before})_1 + (h_{during} - h_{before})_2]$

$P_A \approx 0.5\,(17.0)\,[(14.05 - 13.92) + (14.50 - 13.94)] = 5.87$ watts

and

Loss to C $P_C \approx 0.5\,\dot{m}\,[(h_{during} - h_{before})_1 + (h_{during} - h_{before})_2]$

$P_C \approx 0.5\,(30.0)\,[(12.74 - 12.28) + (13.41 - 13.30)] = 8.55$ watts

The total parasitic loss is then estimated to be 5.87 + 8.55 = <u>14.4 watts.</u>

<u>Mass flow from enthalpy</u>

The mass flow from double pancake B can now be estimated. It is

$$\dot{m} \approx \frac{\underline{P(heater) - P(parasitic)}}{0.25 \sum (h_{during} - h_{before})_i}$$

$$mdot \approx (P_h - P_p) / 0.25\,((h_d - h_b)_{3ca} + (h_d - h_b)_{3co} + (h_d - h_b)_{4ca} + (h_d - h_b)_{4co})$$

$$mdot \approx (151.7 - 14.4) / 0.25\,(20.76 - 13.00 + 20.83 - 13.18 + 19.97 - 12.91 + 21.99 - 13.26)$$

$mdot \approx 137.3 / 0.25\,(31.20) \approx$ <u>17.60 g/s</u>

Mass flow from JAERI meters

The mass flows for the four outlets of B, based on the orifice flow meter calibrations, are calculated using the formula

USMC04 - 07: $\dot{m} = 1.18\ (\rho\ \Delta P)^{0.5}$

The densities and pressure drops required for the mass flow calculation are given in Table 7.8.

Table 7.8 - Supercritical helium absolute pressures, temperatures, densities and pressure drops for mass flow calculations at double pancake B outlets.

Location	Pressure	Temperature	Density	Pressure Drop
	PT04	TC05	NBS 631	MC04
3 - cable	5.15 atm	5.990 K	0.1046 g/cc	95 mm Aq
	PT05	TC06	NBS 631	MC05
3 - corner	5.16	6.000	0.1044	139
	PT06	TC07	NBS 631	MC06
4 - corner	5.13	5.880	0.1081	168
	PT07	TC08	NBS 631	MC07
4 - cable	5.13	6.100	0.0997	108

The mass flows at the outlet of double pancake B are thus calculated to be:

$$\dot{m}\ (3 - \text{cable}) = 1.18\ (0.1046 \text{x} 95)^{0.5} = 3.72\ \text{g/s}$$
$$\dot{m}\ (3 - \text{corner}) = 1.18\ (0.1044 \text{x} 139)^{0.5} = 4.50\ \text{g/s}$$
$$\dot{m}\ (4 - \text{corner}) = 1.18\ (0.1081 \text{x} 168)^{0.5} = 5.03\ \text{g/s}$$
$$\dot{m}\ (4 - \text{cable}) = 1.18\ (0.0997 \text{x} 108)^{0.5} = 3.87\ \text{g/s}$$

The total mass flow from the JAERI meters adds up to 17.12 g/s.

Conclusion

One of the nuclear heating runs has been used to estimate the accuracy of the measured mass flows in the double pancake B. Subject to the stated assumptions, it is concluded that the mass flows calculated from the measured pressure drops across the outlet flow meters, the fluid density, and the equations provided by JAERI are accurate to within 3%. The AC loss measurements should be roughly at this level of accuracy, because the parasitic losses (or gains) to (or from) double pancakes A and C are limited by the small temperature gradients between B and A and C.

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7. J. W. Ekin, "Strain scaling law for flux pinning in practical superconductors. Part 1: Basic relationships and application to Nb_3Sn conductors," Cryogenics, 20:611 (1980).
8. J. W. Ekin and S. L. Bray, National Institute of Standards and Technology, Boulder, Colorado, Private Communication.

8. Series-coil DC test results

In runs 47 - 59 the US-DPC was connected in series electrically with the U1 and U2 and charged by the DC power supply. A maximum current of 25.9 kA was reached before a quench of the U1 coil brought the test to a halt. Figure 8.1 shows the complex charging waveform of run 58, the maximum current run. The waveform reflects the experience of the JAERI staff at charging the U1 and U2 coils to currents above approximately 12 kA. That is, the triangular-wave pattern was thought to be necessary to achieve stability in U1 and U2 during ramps above 12 kA.

The inlet flow conditions of the US-DPC at various times during run 58 are summarized in Table 8.1.

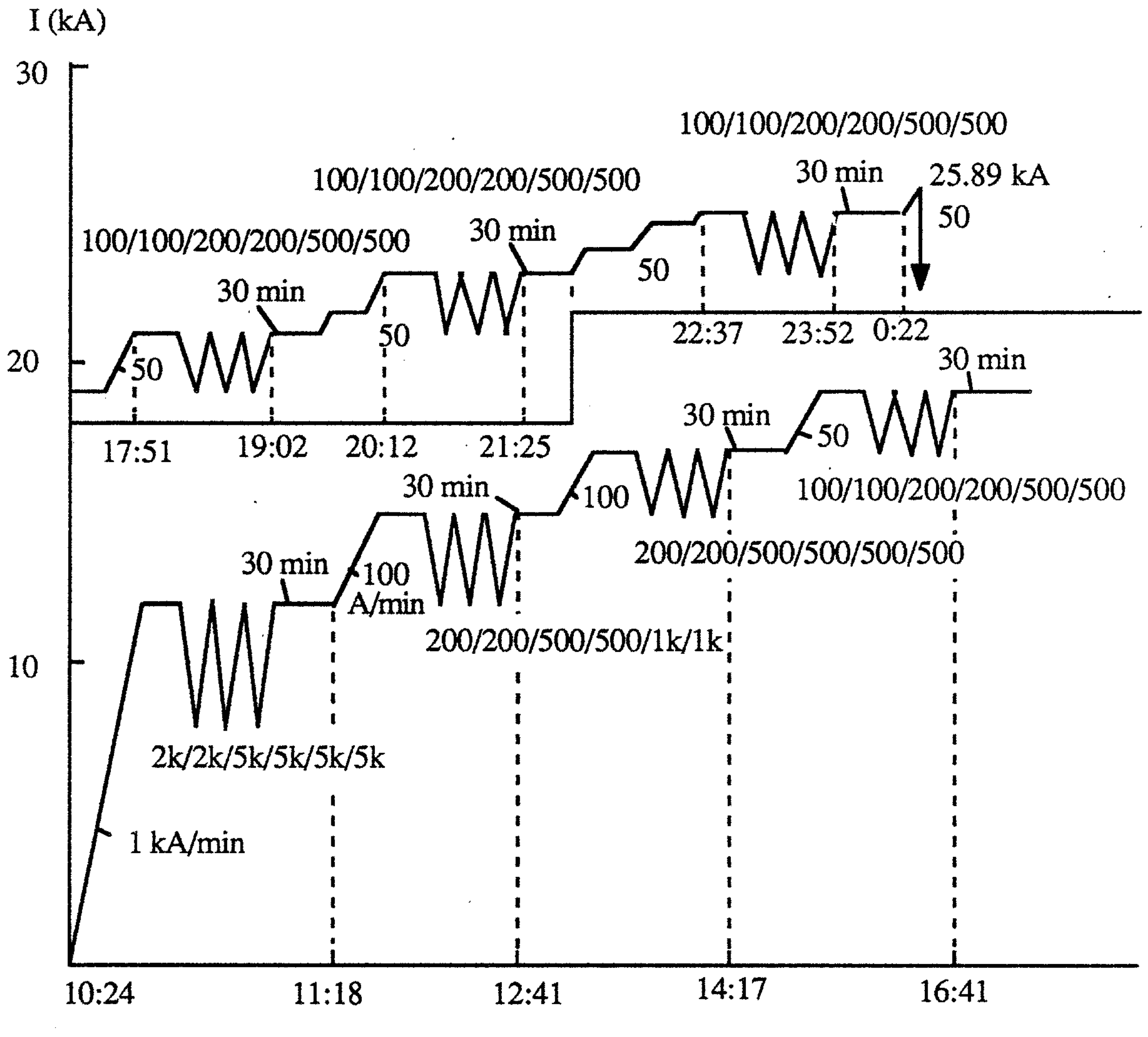


Figure 8.1 - Charging current waveform for maximum-current DC test (run 58). The test began at 10:24 AM on 12/05/90 and ended with a quench at 25.89 kA of the U1 coil at 22 minutes past midnight on 12/06/90. The a/a/b/b/c/c groups denote ramp rates of the triangular wave patterns thought necessary to stabilize the U1 and U2 coils. There was a waiting period of 30 minutes after each triangular-wave pattern before starting the next ramp.

Table 8.1 - The inlet flow conditions at various times during run 58.

Time	Absolute Pressure	Temperature	Mass Flow
10:35	2.45 atm	4.2 K	39 g/s
13:29	4.07	4.2	39
16:53	3.06	4.2	39
19:55	4.32	4.2	39
22:38	4.35	4.2	39
00:25	4.37	4.2	39

9. Single-coil AC test results

AC losses of the US-DPC have been determined by measuring the changes in the thermodynamic state of the supercritical helium exiting the coil during and after each pulse. Although the basic waveforms were trapezoids that had equal upward and downward ramp times, data from other waveforms are reported for purposes of comparison. The AC loss measurement method is based on temperature profiles at the exit, such as the one shown in Figure 9.1, and the assumption that outlet pressures and mass flows were constant. The short-lived pressure and flow fluctuations due to the pulse were on the order of 5 - 10 seconds duration and negligible when compared to the AC loss measurement periods which lasted approximately 200 seconds. For a detailed description of the AC loss measurement technique, see Appendix B. Figure 9.2 shows an index of current-charging waveforms employed during the AC testing of the US-DPC.

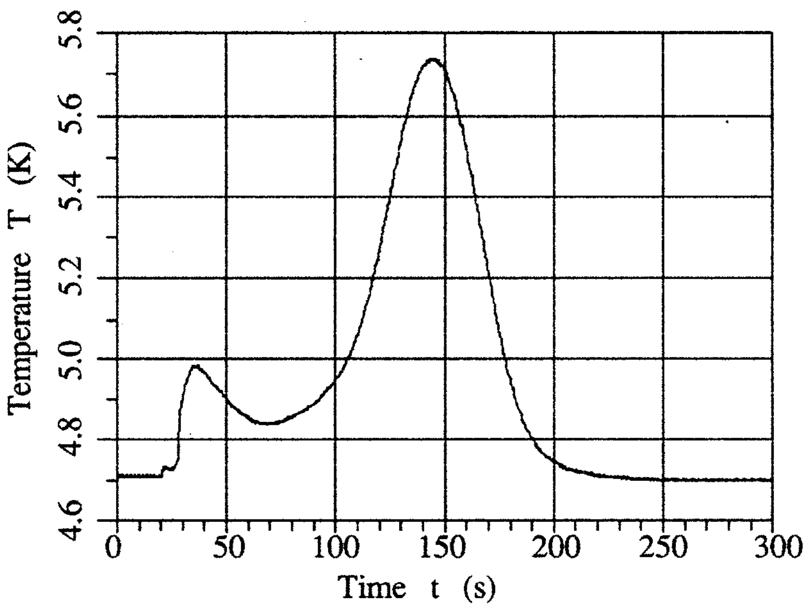


Figure 9.1 - The temperature profile shows a typical measurement of the supercritical helium coolant as it exits the US-DPC. This temperature profile results from a triangular current pulse in the single-coil mode (run 88, pancake 4, corner flow). The absolute pressure was 5.3 atmosphere.

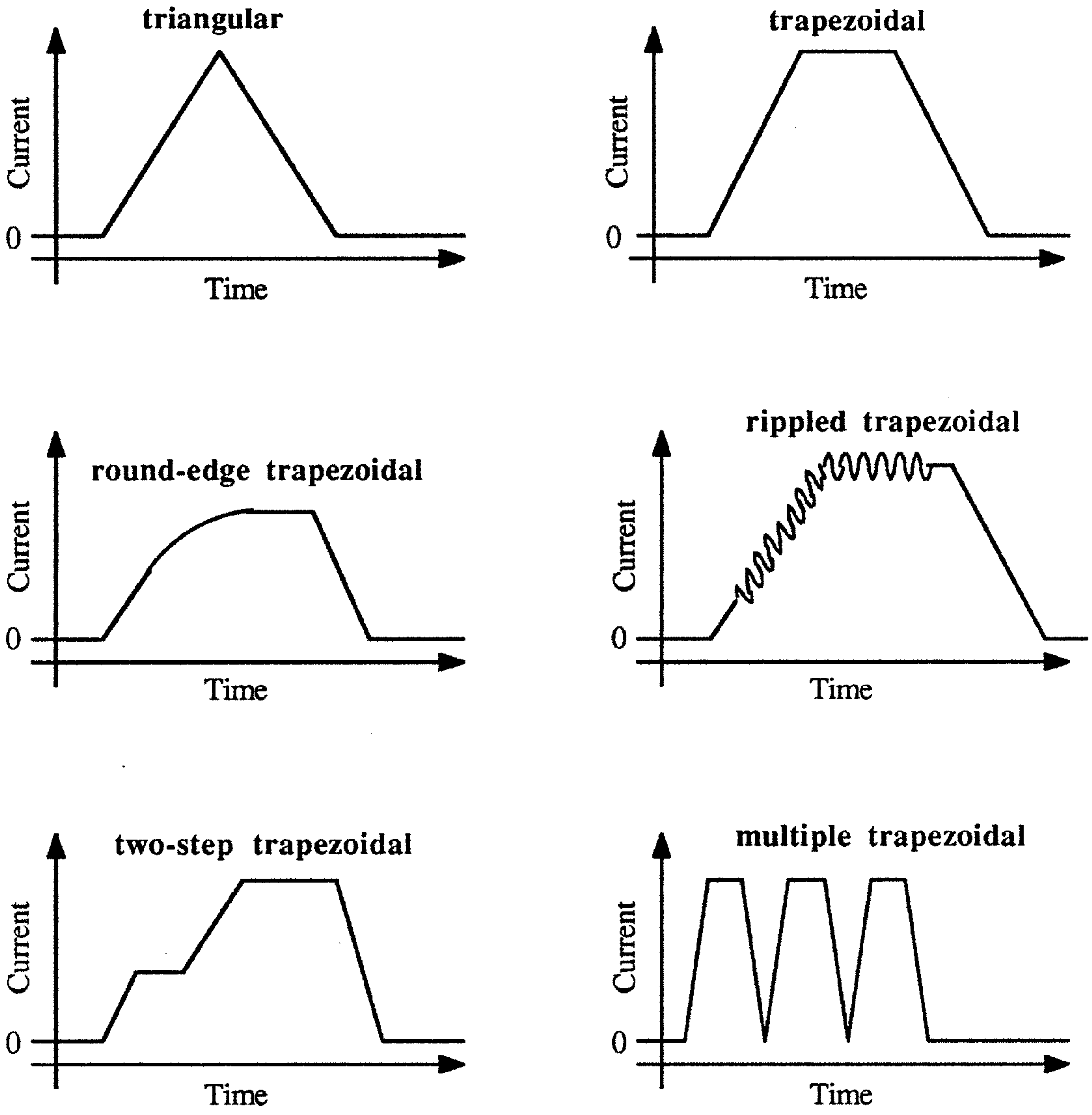


Figure 9.2 - Index of charging waveforms produced by the JT-60 power supply for AC tests of the US-DPC. The power supply was capable of 300 MVA at 60 kA and 5 kV.

9.1 Single-coil coupling and hysteresis losses

The measured losses of the middle double pancake ("B" - pancakes 3 and 4) for symmetrical trapezoidal waveforms are plotted against the reciprocal of ramp time with flattop current as a parameter in Figure 9.3. This type of plot is informative because the loss for a given flattop current, hence field, can be divided into hysteresis and coupling components by reasoning as follows.

Experiments have shown that the hysteresis loss per cycle per unit volume of US-DPC wire subjected to a triangular wave of field with a peak of B_m is approximately

$$Q_h\ [\text{mJ/cc}] = 178.2\ \{1 - \exp(-0.219\ B_m)\} \qquad (9.1)$$

It is evident that the hysteresis loss depends only on the maximum value of current, since field and current are directly proportional. Bundle coupling loss per unit volume of wire, defined as the loss due to eddy currents that circulate between the eighteen filament bundles in the wire, is assumed to account for all the remaining AC loss. For ramps of field it takes the form

$$Q_c\ [\text{mJ/cc}] = 50.68\ \frac{B_m}{t_m} \ln\ (1 + 2.4 \times 10^{-3}\ \text{RRR}\ B_m)] \qquad (9.2)$$

where RRR is the residual resistivity ratio of the copper stabilizer (27.2 for the US-DPC). Combining the two equations shows that in this estimate the total loss depends simply on the maximum current and ramp time t_m. When the maximum current is fixed at some value, a one-over-t_m dependence results

$$Q(\text{fixed } B_m)\ [\text{mJ/cc}] = a + \frac{b}{t_m} \qquad (9.3)$$

where a and b are constants. This is the basis for the form of most of the AC loss plots that follow.

As an example of the division of loss into two parts, refer to Figure 9.3. With a 0.3 s ramp time ($1/t_m = 1/0.3 = 3.33\ s^{-1}$) and 20 kA flattop (run 116), the total loss of double pancake b was 1650 J, with 846 J for hysteresis (at $1/t_m = 0$) and 804 J for coupling. Assuming that the other two double pancakes had comparable losses, the sum of losses for the three is approximately 3 x 1650 ≈ 5000 J, which is 0.14% of the 3.6 MJ stored energy of the coil ($1/2\ LI^2 = 1/2\ (0.0182)(20{,}000)^2 = 3.6$ MJ).

There are two items to be considered in Figure 9.3. First, two data points from triangular current pulses have been included to allow an estimate of the 30kA flattop-current curve. One triangular-pulse point, on the 18 kA curve, is seen to be very close to its trapezoidal-pulse neighbor. The proximity of these two 18 kA points argues for the triangular loss as an estimate of the trapezoidal loss and has allowed a 30 kA curve to be estimated by plotting the curve through the triangular-pulse point at $1/t_m = 2\ s^{-1}$. However, the hysteresis loss estimated by this method is much higher than would be expected from a (1 - exp (-kB)) relationship. The three trapezoidal-pulse data points by themselves project to a more believable hysteresis loss of approximately 1500 J. But these three points indicate an enormously high coupling loss in the 30 kA case. Refer to Section 10.3.2.2.

Second, all data were for 60 g/s total helium flows. Similar current pulses for 30 g/s flows were not included in Figure 9.3 because at the lower flows the mass flow meters were operating below their design and calibration ranges. The 30 g/s data are thought therefore to be less reliable. Figure 9.4 compares loss estimates for 20 kA flattop trapezoidal-pulse runs with total flows of 30 and 60 g/s. The 30 g/s runs result in loss data approximately 50% above the 60 g/s runs. The 60 g/s curve is taken as a calibration of the 30 g/s runs.

The data presented in Figures 9.5 through 9.16 extend the range to include pancakes 2 and 5 as well as 3 and 4. Note that pancakes 1 and 6 have not been included since their outlet helium flowed through the coil leads and absorbed their Joule heating loss, thus making estimates of AC loss unreliable. These figures also show how losses were removed by the dual-flow cooling scheme. It is seen that 50 % or more of the losses were removed by corner flow.

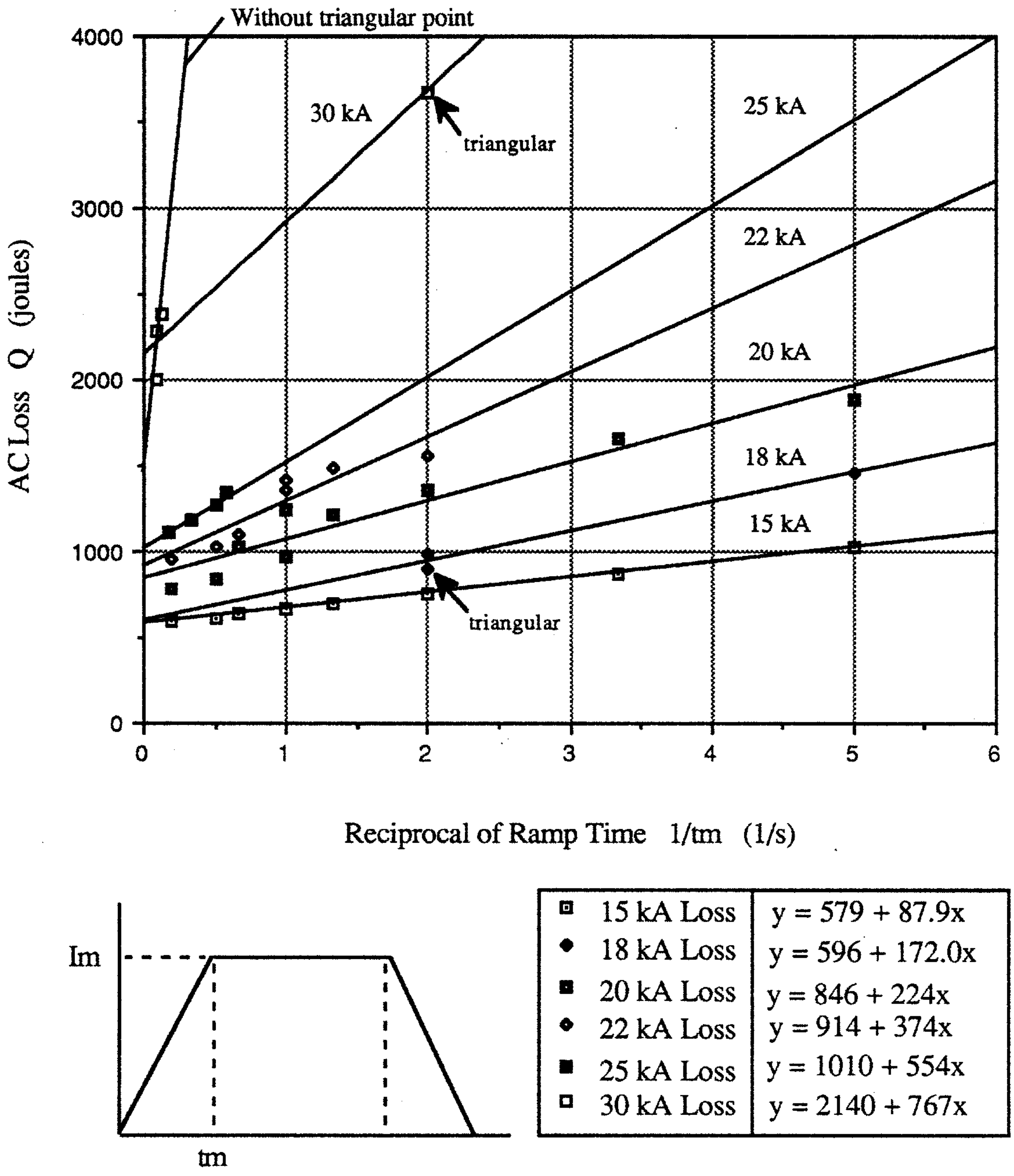


Figure 9.3 - Measured AC loss of pancakes 3 and 4 of the US-DPC for trapezoidal-current pulses in the single-coil mode as a function of the reciprocal of ramp time with flattop current as a parameter. Two triangular pulses are also plotted, one at a peak current of 18 kA and the other at 30 kA. The inlet helium flow conditions were approximately 60 g/s, 6 atm absolute pressure and 4.5 K. The line through the three 30 kA trapezoidal-pulse data points (without triangular point) intersects the vertical axis at a value closer to the expected hysteresis loss.

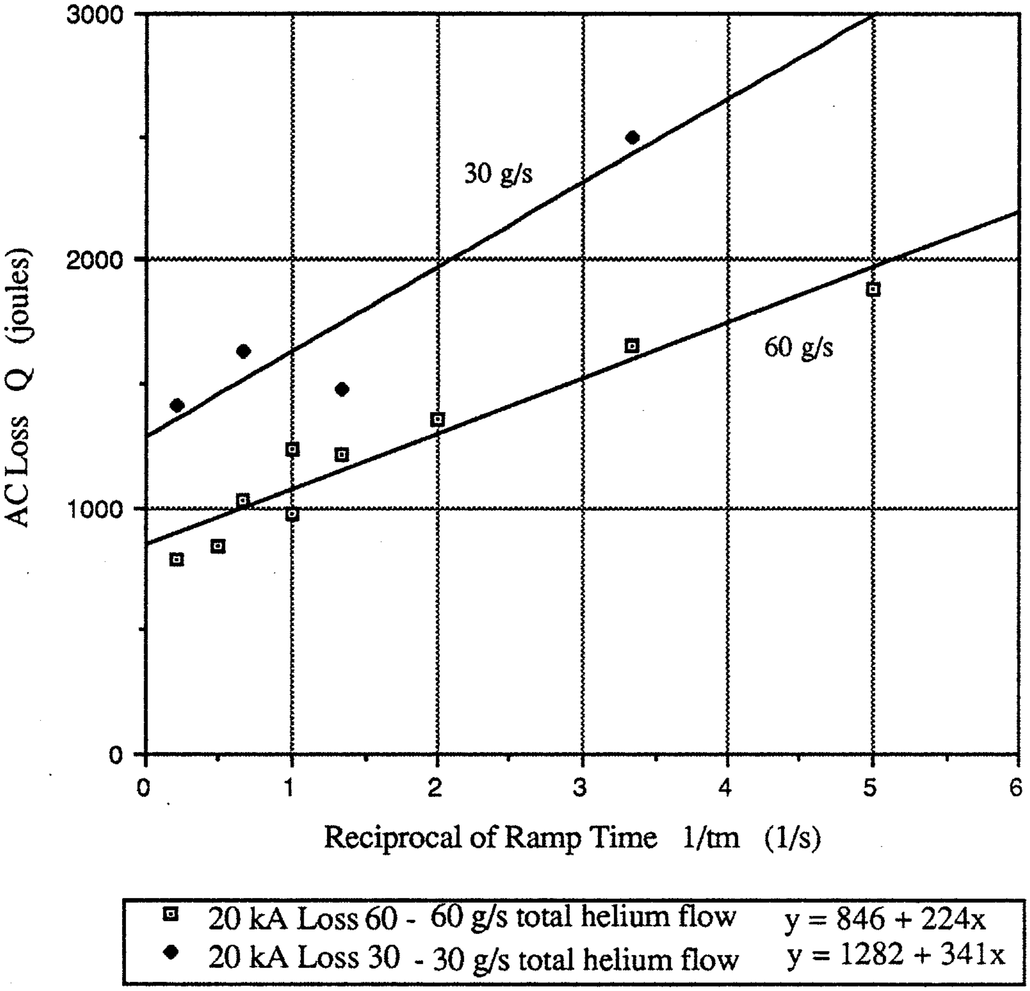
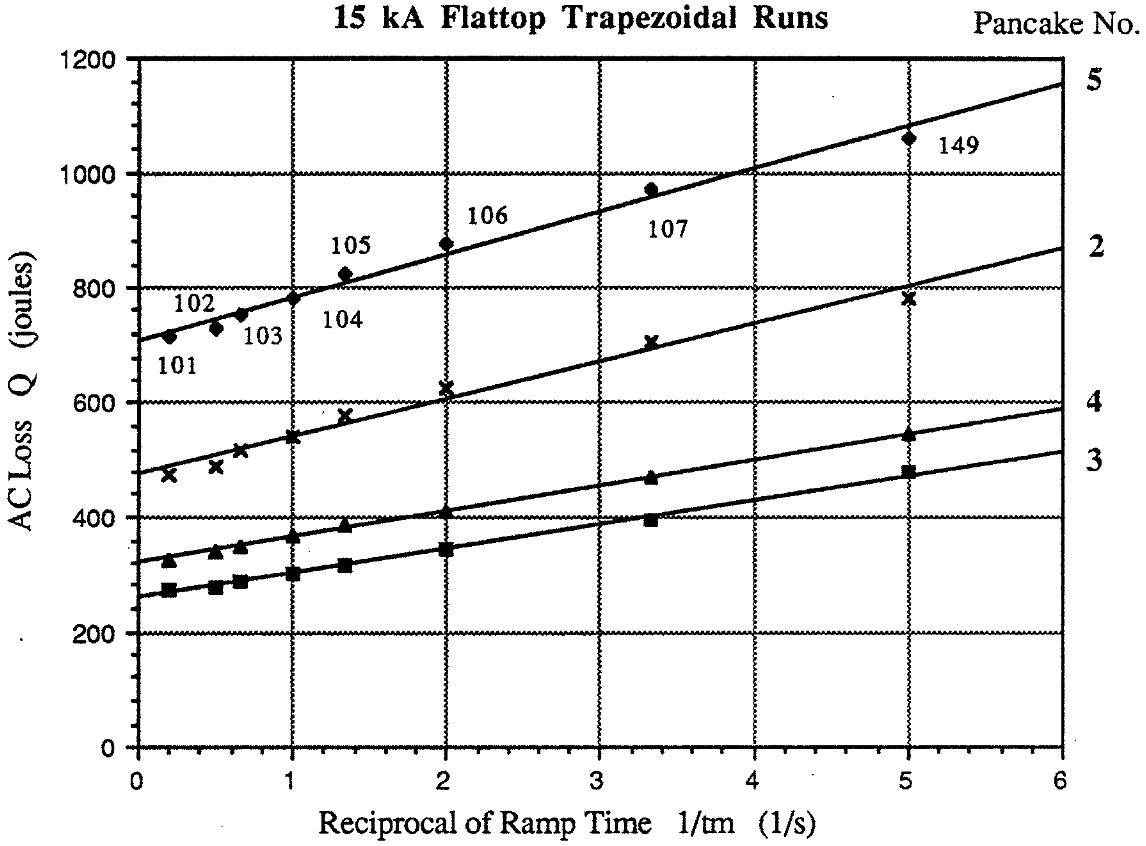
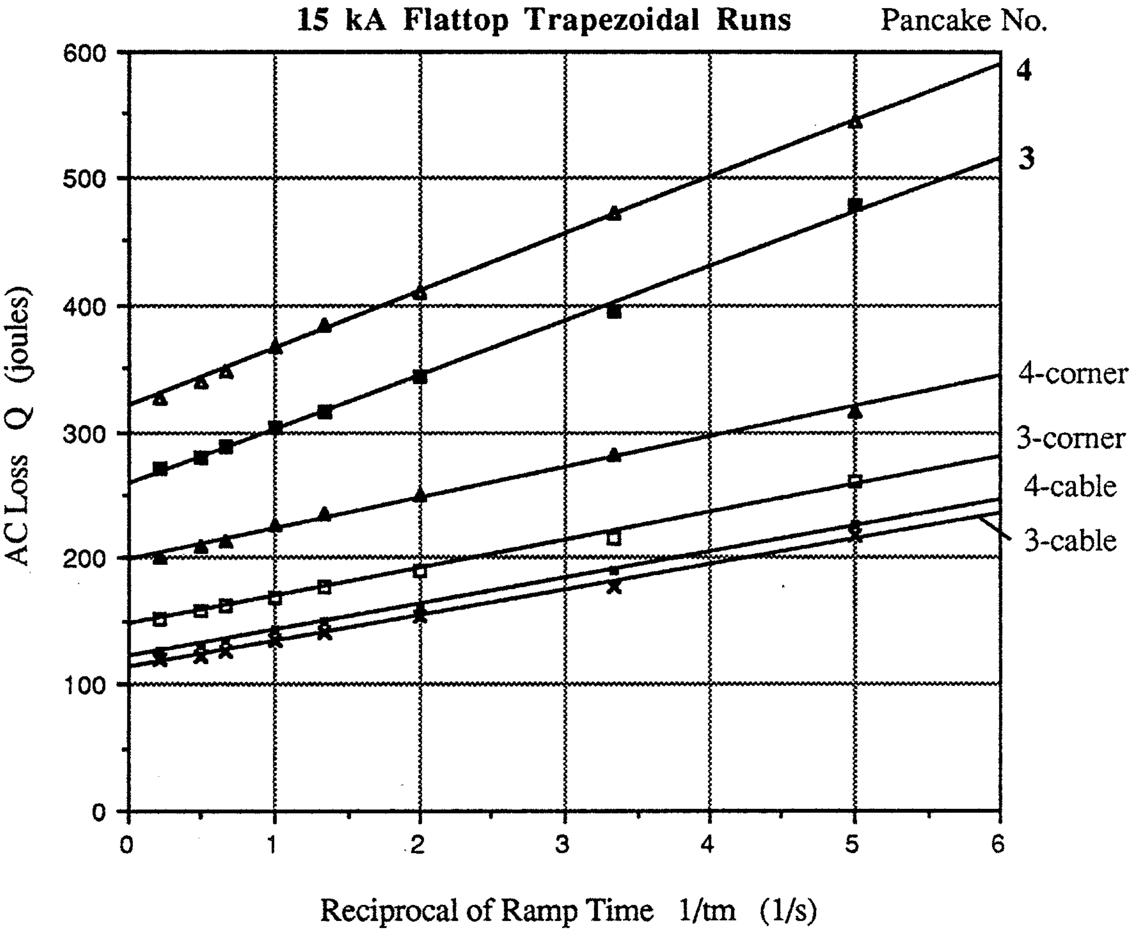


Figure 9.4 - Calibration of 30 g/s runs against more accurate 60 g/s runs. The 30 g/s curve is thought to overestimate losses by approximately 50% due to inaccuracies in the flow measurements in the low-flow range. Measured losses of pancakes 3 and 4 for 20 kA flattop trapezoidal-current pulses in the single-coil mode as a function of the reciprocal of ramp time are plotted.



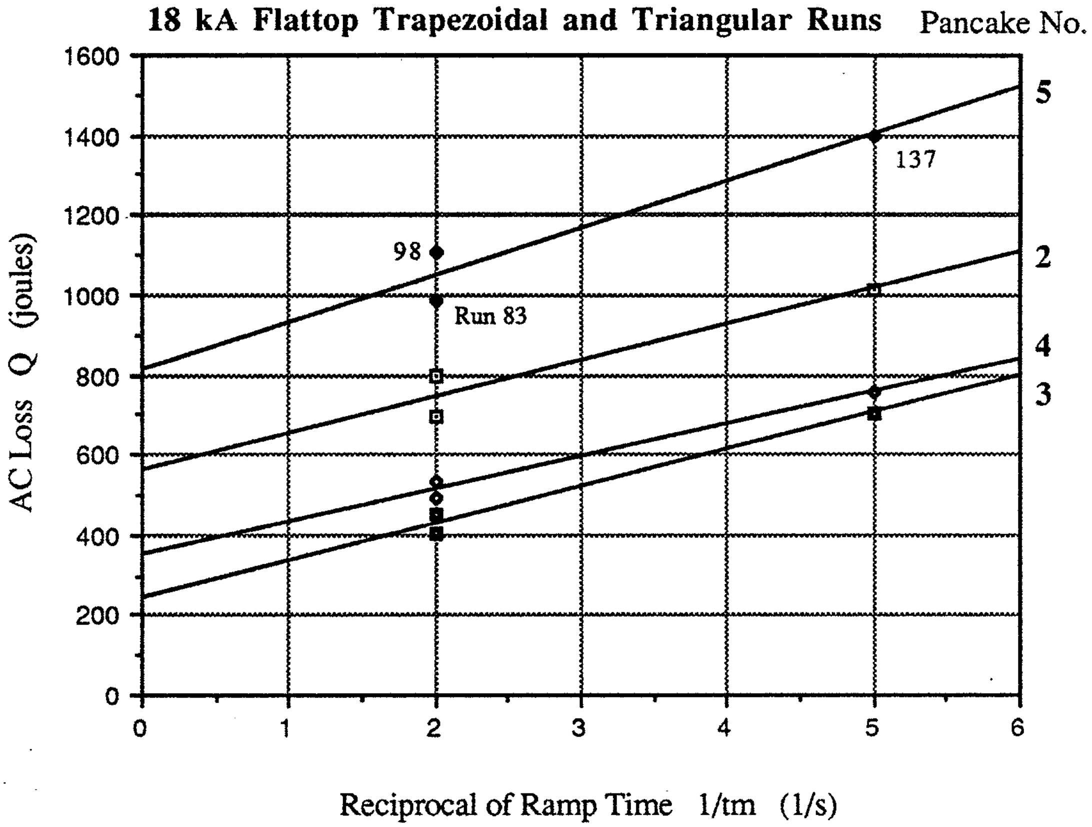
Pancake 5	y = 708 + 74.0x	Pancake 4	y = 319 + 45.3x
Pancake 2	y = 476 + 64.8x	Pancake 3	y = 259 + 42.7x

Figure 9.5 - Measured AC loss for 15 kA flattop trapezoidal-current pulses in the single-coil mode as a function of the reciprocal of ramp time with pancake designation as a parameter. The losses of pancakes 3 and 4 are lower than those of pancakes 2 and 5 due to the field distribution in the single-coil mode (see Figure 6.7).



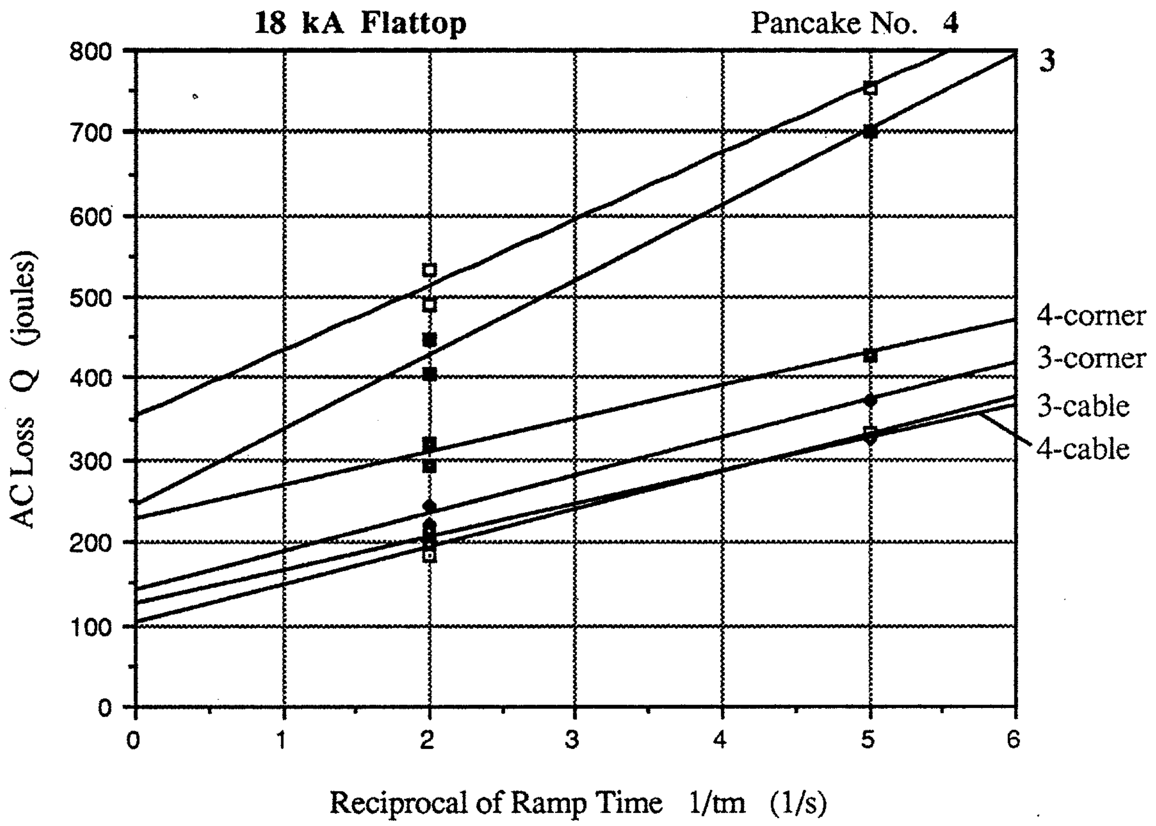
Pancake 3 y = 259 + 42.7x	Cable Pancake 3 y = 113 + 20.5x	Corner Pancake 3 y = 146.5 + 22.1x
Pancake 4 y = 319 + 45.3x	Cable Pancake 4 y = 120.7 + 21.0x	Corner Pancake 4 y = 198.7 + 24.3x

Figure 9.6 - Measured AC loss for 15 kA flattop trapezoidal-current pulses in the single-coil mode as a function of the reciprocal of ramp time for pancakes 3 and 4 with corner-versus-cable flow as a parameter. The plot compares cooling effectiveness of the cable space and corner flow areas - energy removed by corner flow is greater than that removed by cable flow.



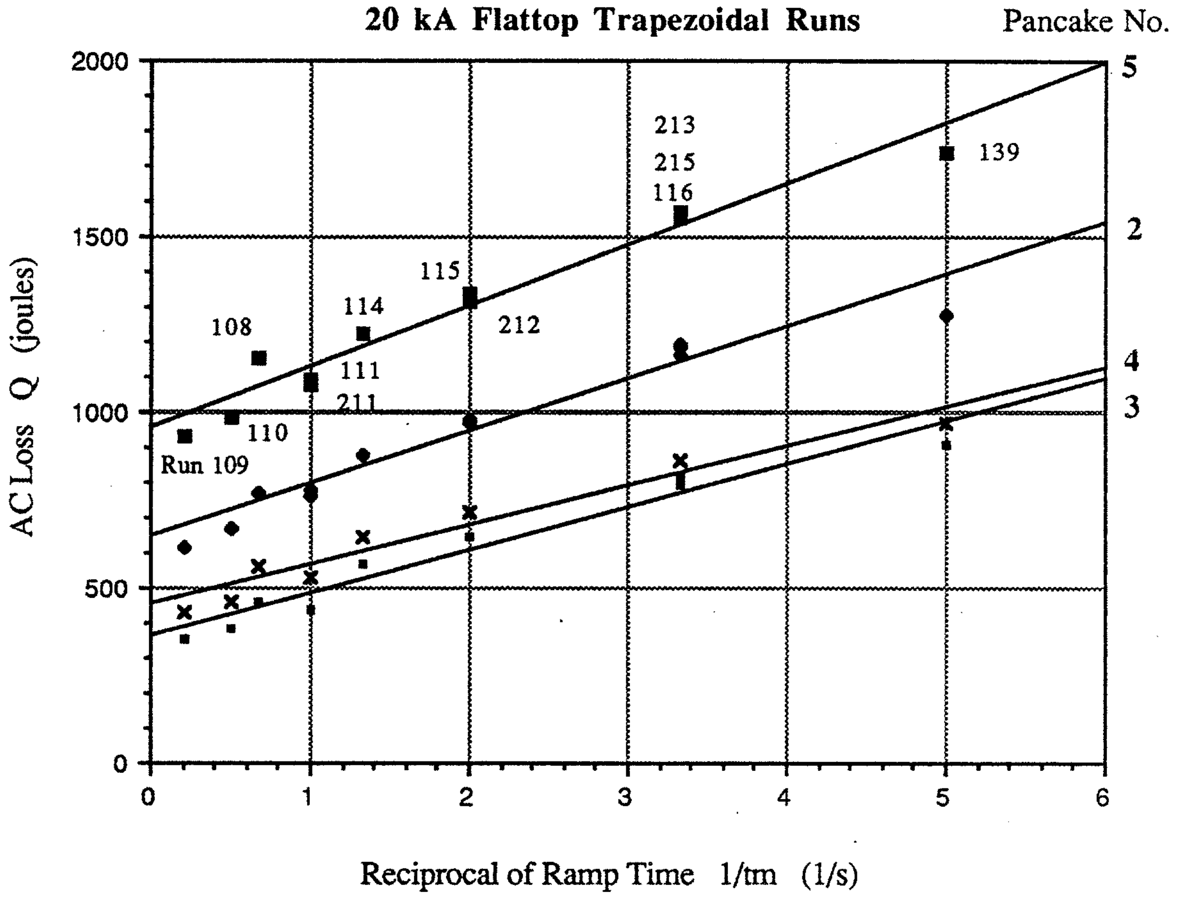
Pancake 5	$y = 812 + 117.2x$	Pancake 4	$y = 352 + 80.5x$
Pancake 2	$y = 563 + 90.2x$	Pancake 3	$y = 244 + 91.7x$

Figure 9.7 - Measured AC loss for 18 kA flattop trapezoidal and triangular current pulses in the single-coil mode as a function of the reciprocal of ramp time with pancake designation as a parameter. Run 83 designates triangular-waveform data.



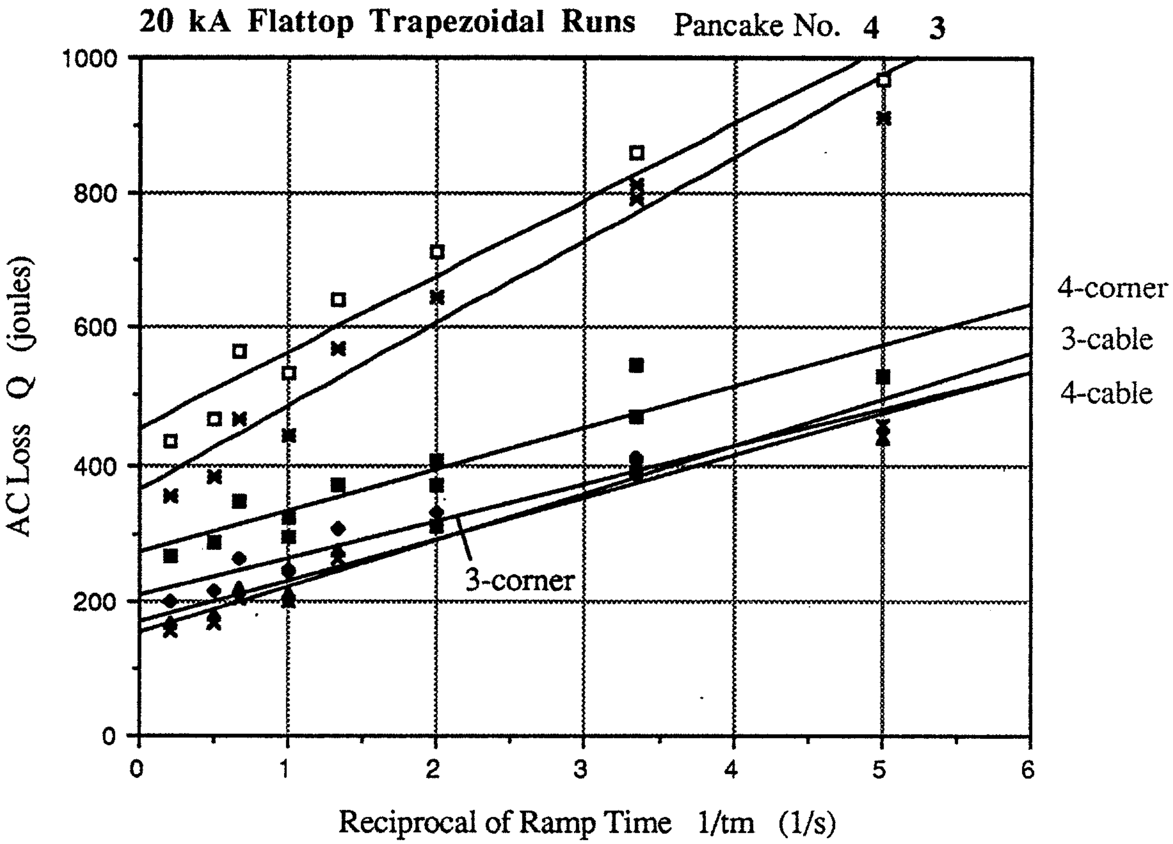
Pancake 3 y = 244 + 91.7x	Cable Pancake 3 y = 102.7 + 45.7x	Corner Pancake 3 y = 141 + 46x
Pancake 4 y = 352 + 80.5x	Cable Pancake 4 y = 126 + 39.8x	Corner Pancake 4 y = 226 + 40.7x

Figure 9.8 - Measured AC loss for 18 kA flattop trapezoidal and triangular current pulses in the single-coil mode as a function of the reciprocal of ramp time for pancakes 3 and 4 with corner-versus-cable flow as a parameter.



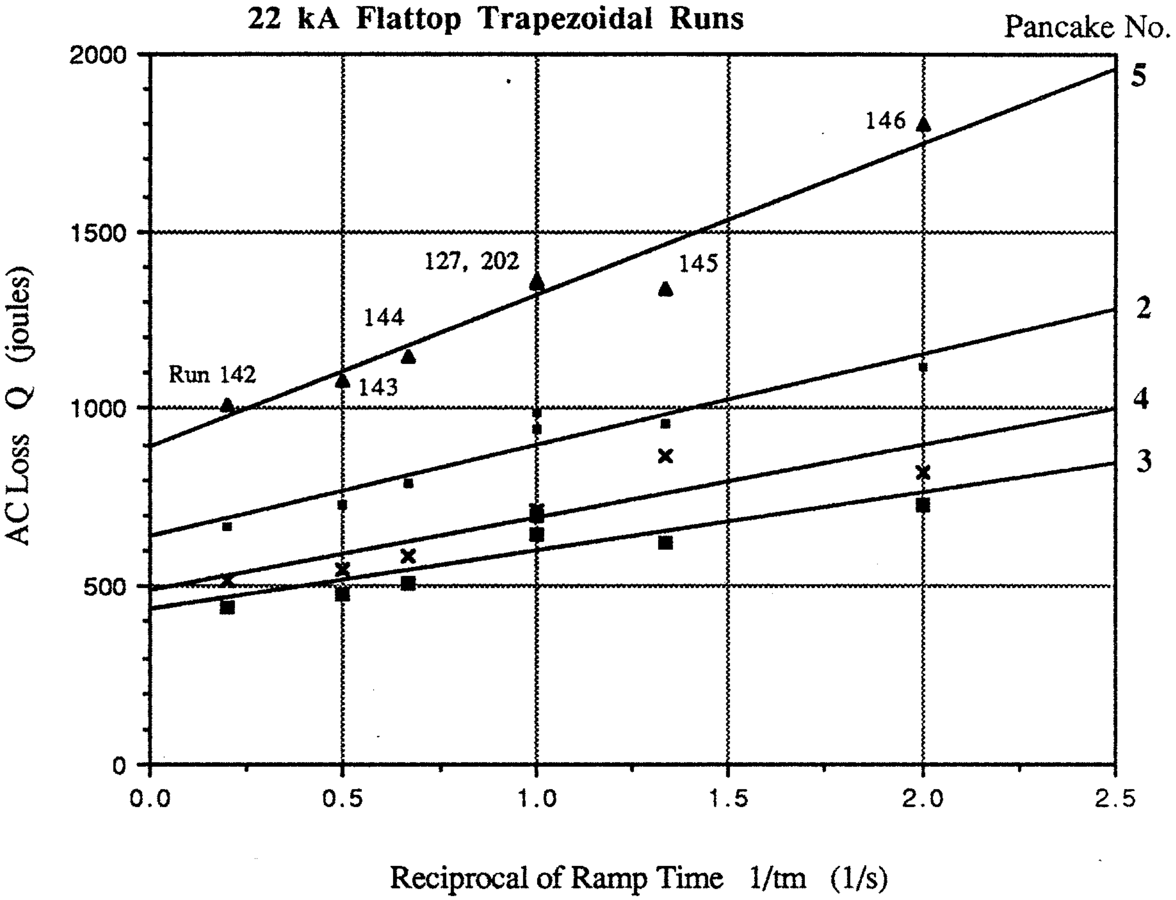
Pancake 2	Pancake 3	Pancake 4	Pancake 5
y = 643 + 148.4x	y = 362 + 122.1x	y = 451 + 112.3x	y = 952 + 174.5x

Figure 9.9 - Measured AC loss for 20 kA flattop trapezoidal-current pulses in the single-coil mode as a function of the reciprocal of ramp time with pancake designation as a parameter. Runs 246 through 249 were omitted due to low mass-flow rates.



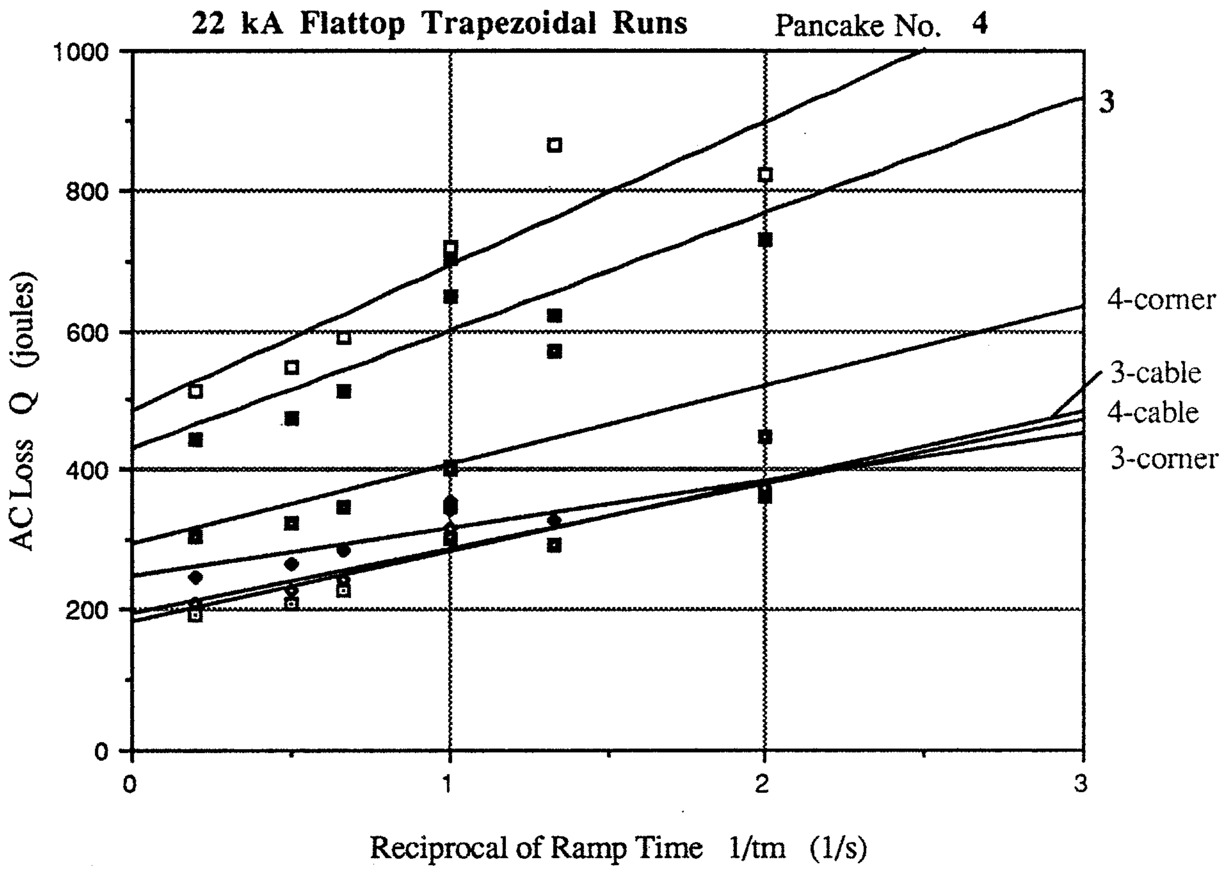
Pancake 3 y = 362 + 122.1x	Cable Pancake 3 y = 152.7 + 68.3x	Corner Pancake 3 y = 206 + 54.4x
Pancake 4 y = 451 + 112.3x	Cable Pancake 4 y = 169.2 + 60.8x	Corner Pancake 4 y = 270 + 60.5x

Figure 9.10 - Measured AC loss for 20 kA flattop trapezoidal-current pulses in the single-coil mode as a function of the reciprocal of ramp time for pancakes 3 and 4 with corner-versus-cable flow as a parameter



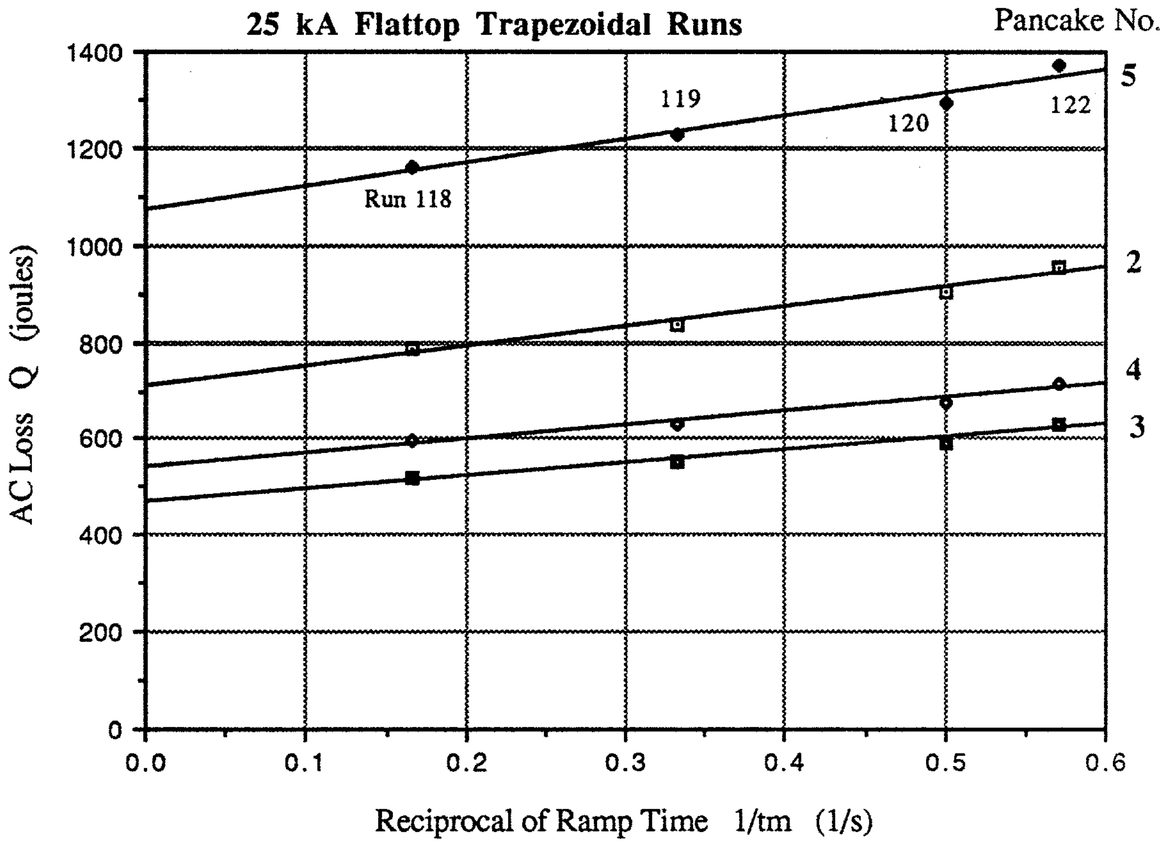
Pancake 5	y = 889 + 429x	Pancake 4	y = 484 + 206x
Pancake 2	y = 642 + 255x	Pancake 3	y = 430 + 168x

Figure 9.11 - Measured AC loss for 22 kA flattop trapezoidal-current pulses in the single-coil mode as a function of the reciprocal of ramp time with pancake designation as a parameter.



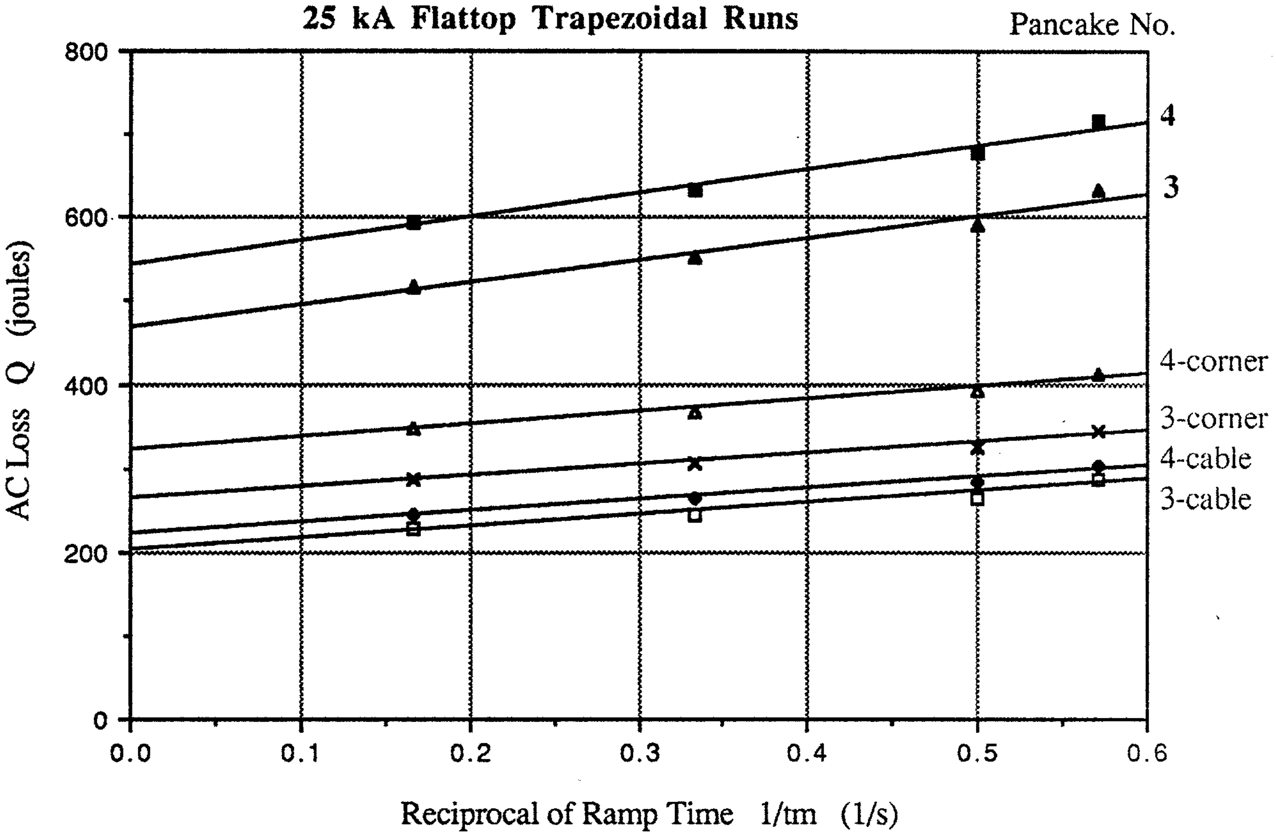
Pancake 3 $y = 430 + 167.9x$	Cable Pancake 3 $y = 180.9 + 100.2x$	Corner Pancake 3 $y = 249 + 67.7x$
Pancake 4 $y = 484 + 206x$	Cable Pancake 4 $y = 192.4 + 92.7x$	Corner Pancake 4 $y = 292 + 113.1x$

Figure 9.12 - Measured AC loss for 22 kA flattop trapezoidal-current pulses in the single-coil mode as a function of the reciprocal of ramp time for pancakes 3 and 4 with corner-versus-cable flow as a parameter.



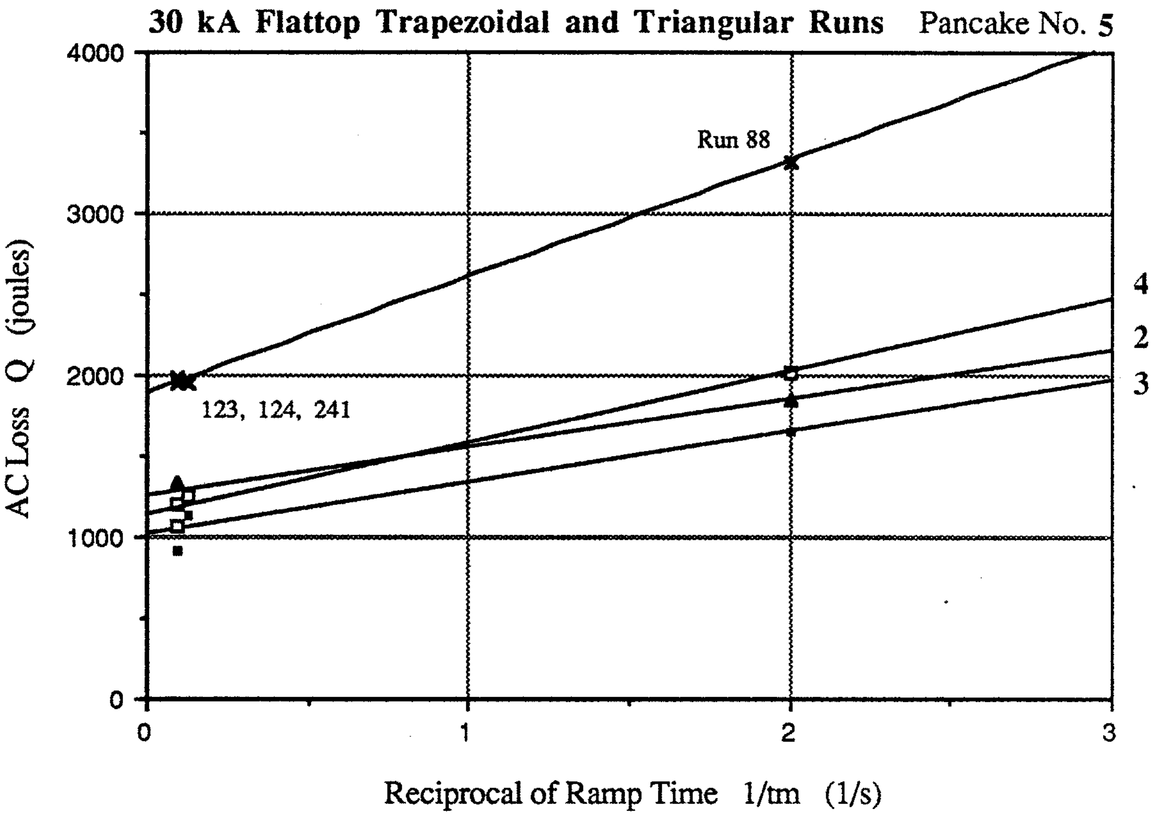
Pancake 5	Pancake 4
$y = 1069 + 493x$	$y = 543 + 284x$
Pancake 2	Pancake 3
$y = 711 + 402x$	$y = 467 + 270x$

Figure 9.13 - Measured AC loss for 25 kA flattop trapezoidal-current pulses in the single-coil mode as a function of the reciprocal of ramp time with pancake designation as a parameter. Run 233 was omitted from this graph due to its low mass flow rate.



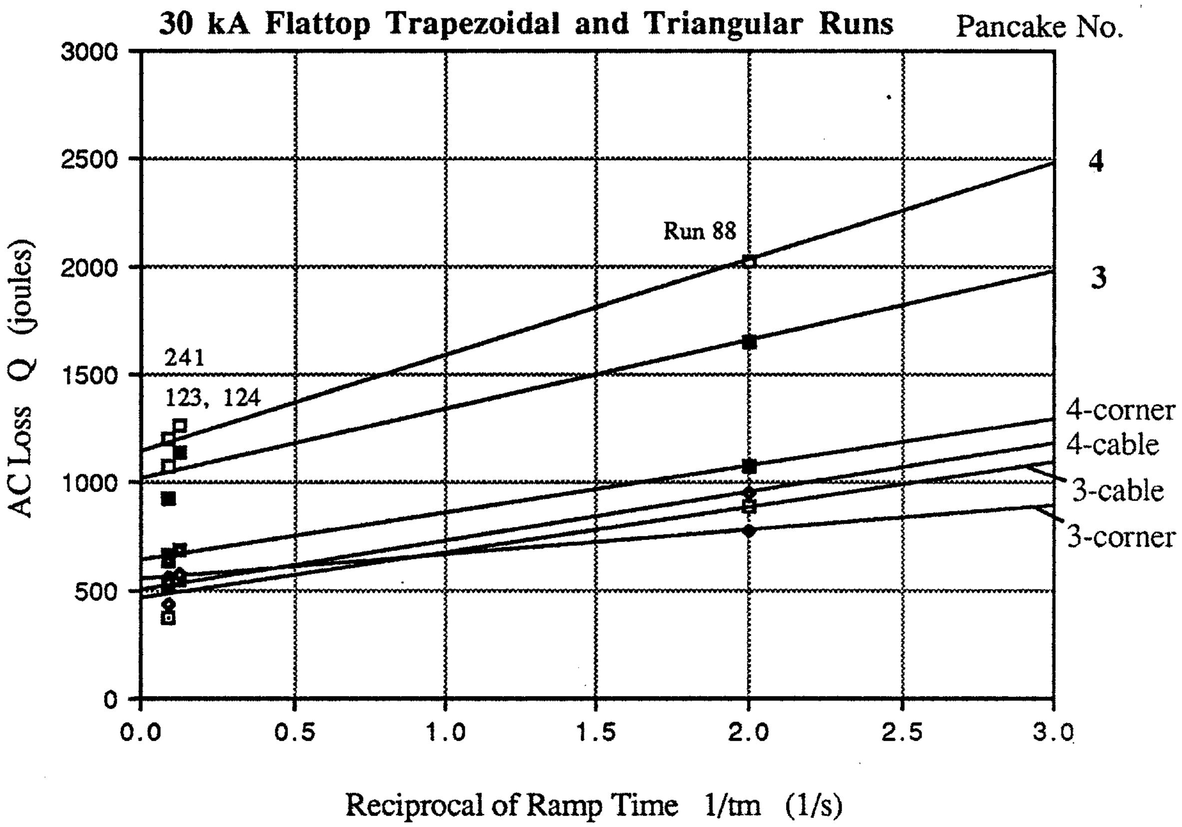
Pancake 3 y = 467 + 270x	Cable Pancake 3 y = 203 + 136.4x	Corner Pancake 3 y = 264 + 133.5x
Pancake 4 y = 543 + 284x	Cable Pancake 4 y = 221 + 134.6x	Corner Pancake 4 y = 322 + 149.7x

Figure 9.14 - Measured AC loss for 25 kA flattop trapezoidal-current pulses in the single-coil mode as a function of the reciprocal of ramp time for pancakes 3 and 4 with corner-versus-cable flow as a parameter.



Pancake 5 y = 1890 + 717x	Pancake 4 y = 1132 + 446x
Pancake 2 y = 1254 + 299x	Pancake 3 y = 1014 + 319x

Figure 9.15 - Measured AC loss for 30 kA flattop trapezoidal and triangular current pulses in the single-coil mode as a function of the reciprocal of ramp time with pancake designation as a parameter. Run 88 designates triangular waveform data.



Pancake 3 y = 1014 + 319x	Cable Pancake 3 y = 463 + 210x	Corner Pancake 3 y = 550 + 109x
Pancake 4 y = 1132 + 446x	Cable Pancake 4 y = 494 + 228x	Corner Pancake 4 y = 638 + 218x

Figure 9.16 - Measured AC loss for 30 kA flattop trapezoidal and triangular current pulses in the single-coil mode as a function of the reciprocal of ramp time for pancakes 3 and 4 with corner-versus-cable flow as a parameter.

Figure 9.17 is a cross plot of data presented previously showing loss as a function of flattop current for constant ramp times. These curves show loss energy to approximately follow a power-law relationship with flattop current:

$$Q = k\,I_m^n$$

where the exponent n lies between 1 and 3 and k is a constant depending on ramp time. Based on the data trend, it is possible or even likely that the 2.0 and 5.0 second curve fits are inaccurate above 25 kA and that the "boundary" curve is given by the 11.0 second ramp time. If this is the case, the exponent may be closer to 2 than to 1 and a current-squared relationship may be a fair approximation of loss energy as a function of transport current in the single-coil case.

Figure 9.18 is a plot of average loss power for the single-coil mode that includes data from both triangular and trapezoidal waveforms. The form of the average loss power expression follows immediately from the loss energy equations 9.1 and 9.2.

$$Q = Q_h + Q_c \qquad (9.4)$$

$$Q = a(1 - e^{-bB_m}) + c\frac{B_m}{t_m}\ln(1 + d\,B_m) \qquad (9.5)$$

where a,b,c and d are constants and $d\,B_m < 1$. Noting that for small values of x

$$e^x \approx 1 + x$$

and for small values of x satisfying $-1 < x \le 1$

$$\ln(1 + x) \approx x$$

it follows that

$$Q \approx f\,B_m + g\,\frac{B_m^2}{t_m} \qquad (9.6)$$

where f and g are constants. Dividing both sides by $2\,t_m$ yields average power during the ramps up and down as a function of ramp rate.

$$P_{avg} = \frac{Q}{2t_m} \approx \frac{f}{2}\left(\frac{B_m}{t_m}\right) + \frac{g}{2}\left(\frac{B_m}{t_m}\right)^2 \qquad (9.7)$$

It is evident from the figures that this relationship applies fairly well.

Figure 9.19 is a plot of average AC loss power versus current ramp rate for the series mode. Although there are only a few data points, the trapezoidal data fit the two-term loss expression quite well. The series-loss data appear to be roughly equal in magnitude to the single-coil-loss data.

Figure 9.20 is a plot of AC loss versus the reciprocal of ramp time for a two-step trapezoidal current pulse. Note that the time to the maximum current flattop is defined as having three components in this case: the first ramp time, the first flattop time and the second ramp time. Since this type of waveform is more difficult to deal with than a simple trapezoid, the dimensions of the current pulses and the loss data are listed in Table 9.1.

Figure 9.21 shows hysteresis losses for pancakes 2 - 5, where hysteresis loss is defined as the y-intercept value of the measured AC-loss vs. reciprocal of ramp time. Note that the losses above 25 kA may include joule heating as explained in Section 10.3.2.2.

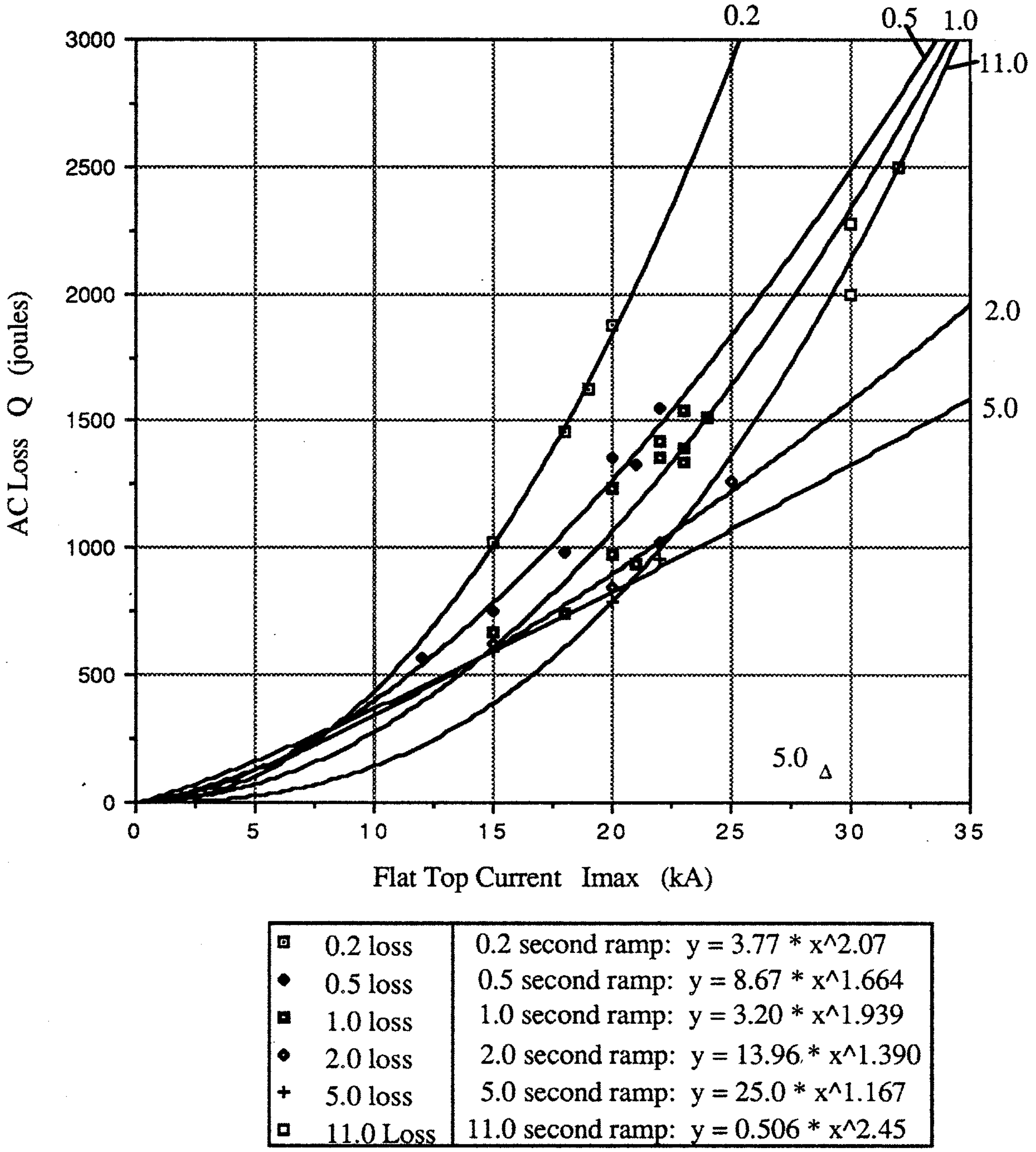


Figure 9.17 - AC loss of pancakes 3 and 4 as a function of flattop current in the single-coil mode with ramp time as a parameter. Note that the data point denoted by an open triangle was not included in the 5.0 s curve fit. Ramp rate is obtained by dividing flattop current by ramp time.

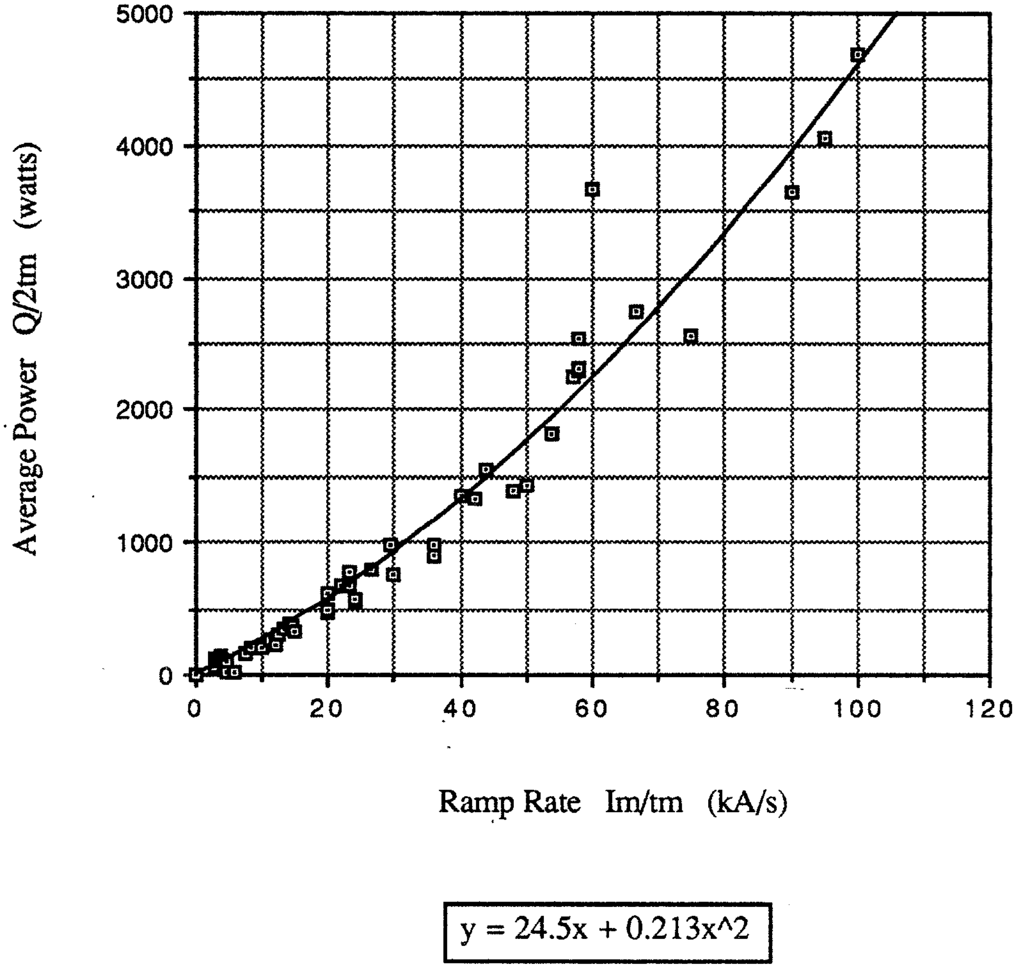


Figure 9.18 - Average AC loss power of pancakes 3 and 4 in the single-coil mode as a function of current ramp rate. Included in the data are both trapezoidal and triangular current pulses. Maximum field ramp rate is obtained by multiplying Im/tm by (5.66 T / 30 kA).

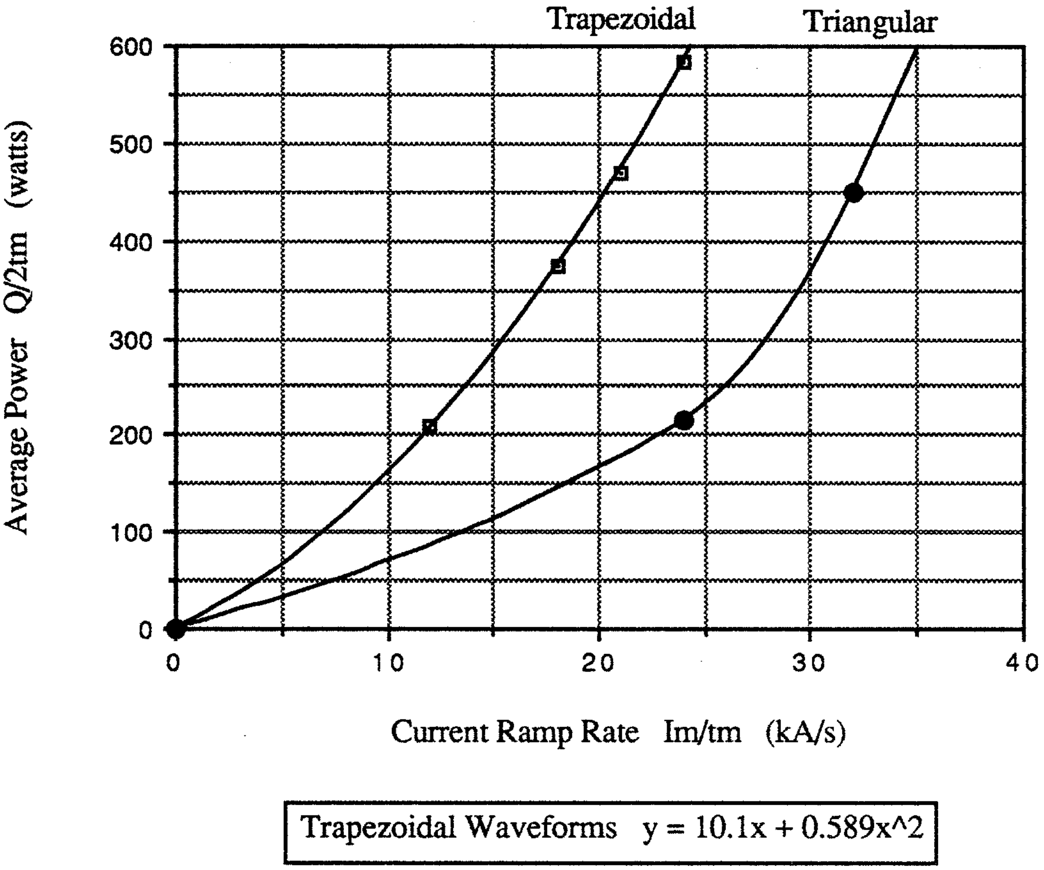


Figure 9.19 - Average AC loss power of pancakes 3 and 4 in the series mode as a function of current ramp rate. Maximum field ramp rate is obtained by multiplying Im/tm by (9.22 T / 30 kA).

Table 9.1 - Dimensions of current pulses and AC loss data for the 2-step trapezoidal runs plotted in Figure 9.20. I_1 is defined as the first flattop current.

Run	I_l	I_{max}	t_1	t_2	t_3	t_4	Loss
195	20 kA	25 kA	4.0 s	3.0 s	1.0 s	5.0 s	1204 J
196	20	25	1.6	3.0	0.4	2.0	1264
197	20	25	0.8	3.0	0.2	1.0	1520
198	20	25	0.4	3.0	0.1	0.5	1983

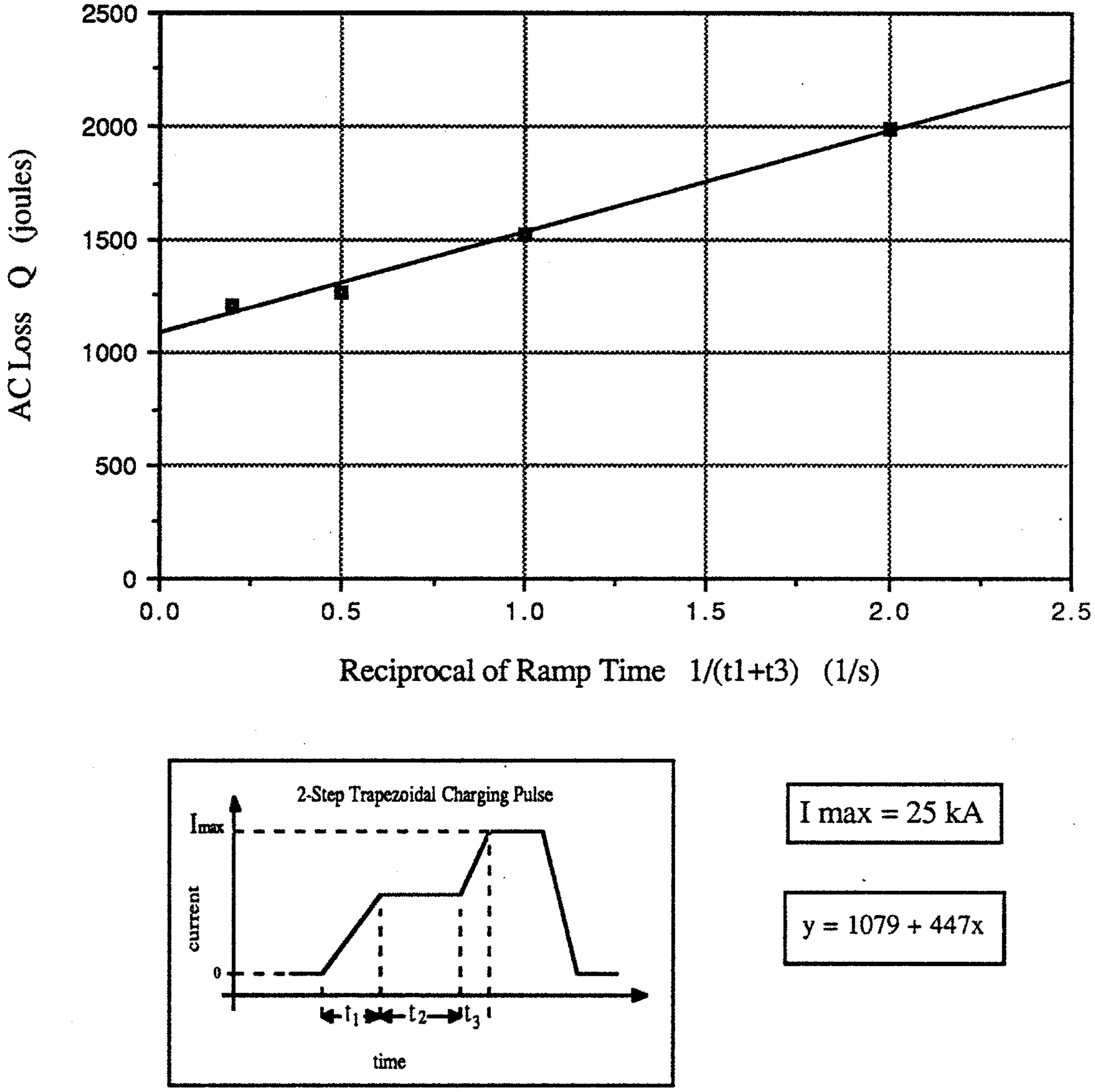


Figure 9.20 - Measured AC loss for 2-step trapezoidal current pulses as a function of the reciprocal of ramp time for maximum flattop currents of 25 kA. Note that the fall time t4, not shown on the diagram, equals the sum of t1 and t3.

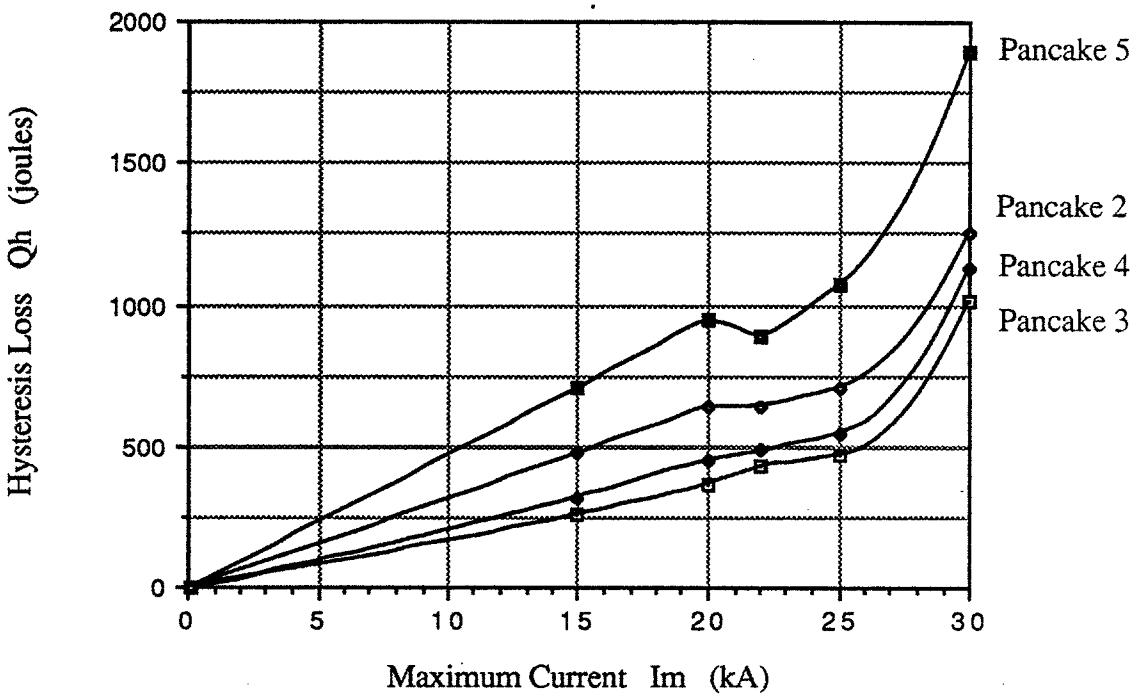


Figure 9.21 - Hysteresis losses of pancakes 2 - 5 in the single coil mode as a function of maximum current with pancake designation as a parameter.

9.2 Estimate of effective filament diameter

Section 9.2 outlines the analysis used to calculate the effective filament diameter D_{eff} of the US-DPC wire and presents the results. In section 9.2.1, the detailed equation for the critical current is explained as well as the procedure used to find D_{eff}. In section 9.2.2, the measured hysteresis loss is used to find the effective filament diameter. The D_{eff} value obtained from the US-DPC tests is then compared with the D_{eff} value obtained from single wire measurements. Finally, a sensitivity study is presented which investigates (1) the effect that the variation of strain and temperature have on the D_{eff} calculation and (2) the effect that the detailed critical-current equation (compared to a simple exponential equation) has on the D_{eff} calculation.

9.2.1 Analytical model

The hysteresis loss of a round superconductor in a perpendicular triangular-ramp field with an amplitude much higher than the penetration field, can be described as shown in Equation 9.4 below[1].

$$Q_{h,\,\mathrm{ramp}}\ [\mathrm{Joule/m^3\ of\ wire}] = \frac{8}{3\pi}\int_{B_0}^{B_m} \lambda\, J_c(B)\, a\, dB \qquad (9.4)$$

where λ is the volume fraction of the non-copper materials in the wire, $J_c(B)$ [A/mm^2] is the critical current density of the non-copper region, B [T] is the external field which varies between B_m and B_0, and a [m] is the filament radius. Equation 9.4 was derived from Bean's critical-state model and is adopted here as first-order estimation of the hysteresis loss. For a known loss, the effective filament diameter, D_{eff}, is evaluated as shown in Equation 9.5.

$$D_{eff}\ [\mathrm{m}] = \frac{3\pi}{4}\,\frac{Q_{h,\mathrm{ramp}}^{\mathrm{measured}}\ [\mathrm{Joule/m^3}]}{\displaystyle\int_{B_0}^{B_m} \lambda\, J_c(B)\, dB} \qquad (9.5)$$

As seen in Equation 9.5, the effective filament diameter depends heavily on the critical current density function.

Two functions that fit the experimental data are available. The first one, given in Equation 7.1 and reproduced in Equation 9.6, is obtained from a model described by Summers et al[2].

$$J_c(B,\,T,\,\varepsilon) = \frac{C(\varepsilon)\,(1 - t^2(T,\,\varepsilon))^2\,(1 - b(B,\,T,\,\varepsilon))^2}{B_{c2}^{0.5}(T,\varepsilon)\ \ b^{0.5}(B,\,T,\,\varepsilon)} \qquad (9.6)$$

where

$J_c(B,T,\varepsilon)$ is in A/mm^2 of non-copper
$C(\varepsilon) = C_0(1 - a\,|\varepsilon|^{u})^{1/2}$
C_0 = coefficient independent of field, temperature, and strain
$t(T,\varepsilon) = T/T_{c0}(\varepsilon)$
$B_{c2}(T,\varepsilon) = B_{c20}(\varepsilon)(1-t^2)\{1 - 0.31\,t^2(1 - 1.77\ln t)\}$
$B_{c20}(\varepsilon) = B_{c20m}(1-a|\varepsilon|^{u})$
$b(B,T,\varepsilon) = B_{c2}(T,\varepsilon)$
$T_{c0}(\varepsilon) = T_{c0m}(1-a|\varepsilon|^{u})^{1/w}$
$a = 900$ for $\varepsilon < 0$, 1200 for $\varepsilon > 0$
$u = 1.7$
$w = 3$

The four fitting parameters are B_{c20m}, T_{c0m}, C_0, and ε.

In addition to field, Equation 9.6 includes the effects of temperature and strain on critical current density. Thus, a single equation can be used to describe the same conductor tested in different background conditions.

With $B_{c20m} = 27.5$ T, $T_{c0m} = 16$ K and $C_0 = 8800$ A $T^{1/2}$ mm^{-2}, Equation 9.6 fits the critical current data best with $\varepsilon = -0.001$ for the US-DPC measurement, and $\varepsilon = -0.0036$ for the single-wire measurement.[3]

A second function in exponential form, where $J_{c,w}(B)$ is in A/mm^2 of non-copper is

$$J_{c,w}(B) = 5972\, e^{-0.2162\, B}\,, \quad \text{for } 2.5\text{ T} < B < 15\text{ T} \tag{9.7}$$

This fits the measured data for single-wire barrel tests that depend on applied field only.

The integration in Equation 9.5 should be started from $B_0 = 0$ T if the external field was changed from zero to a maximum value then returned to zero. However, Equation 9.6 is not valid as the external field approaches zero because the critical current is limited by self field. In order to do the integration without introducing a large error, the critical current density at near-zero external field, J_{c0}, is estimated by linear extrapolation of the single-wire results. Note that the J_{c0} is by no means the real zero field critical current density. By letting $J_c(B^*, T, \varepsilon) = J_{c0}$ in Equation 9.6, a B^* can be found which is the new lower bound of the integration, ie. $B_0 = B^*$ in Equation 9.5.

The constants to be used in computing the effective filament diameter are $J_{c0} = 1.76 \times 10^{10}$ (A/m^2 of non-Cu) and $B^* = 0.169$ T. The total area will be the sum of a constant area $J_{c0}B^*$ and the integration started with a non-zero field, B^*.

The field distribution along the radial direction of a double-pancake winding is highly non-uniform. Therefore, the integration of the critical current density over the applied field is calculated turn-by-turn. The total loss is the sum of the losses in all the turns of the double pancake. By substituting Equation 9.6 into Equation 9.5, the effective filament diameter in meters is expressed as shown in Equation 9.8.

$$D_{eff} = \frac{Q_{h,ramp}^{measured}\ \text{[Joule/m}^3\text{ wire]}}{\frac{4}{3\pi}\lambda \sum_{n=1}^{N} \frac{V_n}{V_{tot}} \left[J_{c0}B^* + C\, B_{c2}^{0.5} (1-t^2)^2 \left(2b^{0.5} - \frac{4}{3}b^{1.5} + \frac{2}{5}b\right)\Big|_{b^*}^{b_{m,n}} \right]} \tag{9.8}$$

where $b_{m,n} = B_{m,n}/B_{c2}$ is the dimensionless maximum field of the nth turn in the pancake winding, $b^* = B^*/B_{c2}$ is the dimensionless lower bound of the integration, V_n is the volume of the superconducting cable in the nth turn, and the V_{tot} is the total volume of the superconducting cable in the double pancake.

9.2.2 Effective filament diameters

In the US-DPC tests, the ratio of transport to critical current was less than 40% in the highest field region. From single-wire AC loss measurements shown in an earlier article[4], the additional loss due to the transport current was estimated to be less than 5% and thus was neglected in the present analysis.

The AC-loss results from double pancake B have been selected for computing the effective filament diameters. Refer to Figure 9.21. By using Equation 9.8, the best-fit effective filament diameter is found to be 19.8 μm when data at 30 kA are neglected. The variation is about 30%, with a maximum of 23 μm at 25 kA and a minimum of 17.5 μm at 15 kA.

Similar calculations using Equation 9.8 have been performed for single-wire losses, and the best-fit D_{eff} is found to be 21.8 μm with a variation of about 10%.[4] It is concluded that the effective filament diameters from two experiments with very different conditions are in reasonable agreement. Computed hysteresis losses (Eqn 9.4) using these best-fit diameters are compared to US-DPC data in Figure 9.22.

The sensitivity of effective filament diameter to variations in temperature and strain has been examined using Equation 9.8. The procedure uses single-wire temperature and strain values ($T = 4.2$ K and $\varepsilon = -0.0036$) and the US-DPC field distribution. The resulting effective diameters are listed in Table 9.2 (cases 3 to 5) along with those calculated at standard US-DPC and single-wire conditions (cases 1 and 2). The variations of effective diameter are within 3% of 19.8 μm. Therefore, the hysteresis loss and the D_{eff} calculation using the J_c model of Equation 9.6 are not very sensitive to temperature and strain effects in the range considered.

Table 9.2 also includes a sensitivity study made by applying the exponential J_c model to estimate effective diameters. Both the US-DPC and the single-wire diameters are recalculated by substituting Equation 9.7 into Equation 9.5. This yields 38 μm as the best-fit of the US-DPC data and 28 μm as the best fit of the single-wire data. The former agrees fairly well with that estimated by JAERI (45 μm).[5]

Comparing cases 2 and 7, the disagreement in effective diameters is about 35%, which is caused by the different J_c distributions in the low-field region (< 2.5 T). Due to the non-uniform field distribution along the US-DPC conductor, 10% ($I_m = 25$kA) to 25% ($I_m =$ 15kA) of the cable volume sees an applied field lower than 1 T. The underestimation of the low-field J_c thus becomes more apparent to the D_{eff} evaluation for the US-DPC than for the single wire. As seen in Table 9.2, the D_{eff} in case 6 is 30% higher than in case 7 when same J_c model is applied, and a factor of 2 higher than in case 1 (better J_c model). One may conclude that the low-field critical current distribution is more important than temperature and strain effects in calculating hysteresis loss and effective filament diameter.

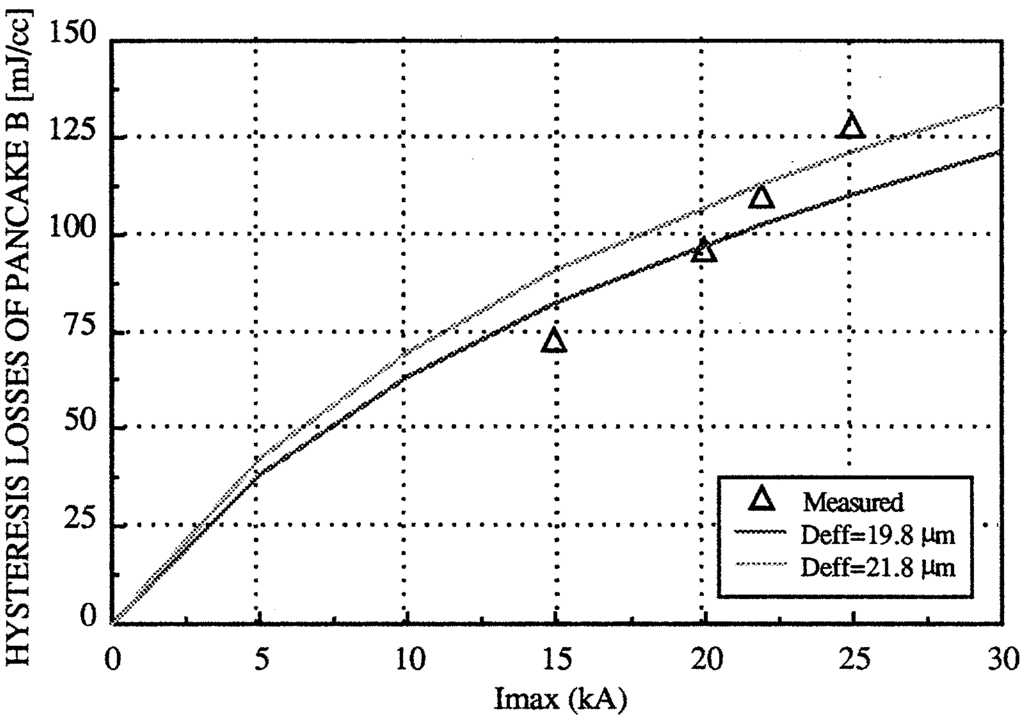


Figure 9.22 - Comparison of the US-DPC extrapolated hysteresis losses with the calculated hysteresis losses using the best-fit effective filament diameters. D_{eff}= 21.8 μm is estimated from the single-wire experiment, and D_{eff} = 19.8 μm from the US-DPC experiment. Data at 30 kA are considered less reliable and have been neglected in this comparison.

Table 9.2 - Comparisons of effective filament diameters.

Case	Q_h (measured)	J_c model	Test	T[K]	ε [%]	D_{eff} (μm)
1	US-DPC (4.5 K)	$J_c(B, T, \varepsilon)$	US-DPC	4.5	-0.1	19.8
2	single wire (4.2 K)	$J_c(B, T, \varepsilon)$	single-wire	4.2	-0.36	21.8
3	US-DPC (4.5 K)	$J_c(B, T, \varepsilon)$	US-DPC	4.2	-0.36	20.1
4	US-DPC (4.5 K)	$J_c(B, T, \varepsilon)$	US-DPC	4.5	-0.36	20.4
5	US-DPC (4.5 K)	$J_c(B, T, \varepsilon)$	US-DPC	4.2	-0.1	19.4
6	US-DPC (4.5 K)	$J_{c,w}(B)$	US-DPC	4.2	----	38
7	single wire (4.2 K)	$J_{c,w}(B)$	single-wire	4.2	----	28

References

1. M.N. Wilson, "Superconducting Magnets", Clarendon Press, Oxford (1986).
2. L.T. Summers et al., A Model for Prediction of Nb_3Sn critical Current as a Function of Field, Temperature, Strain, and Radiation Damage, IEEE Trans on Mag, MAG-27, No. 2 (1991), p. 2041.
3. M. Takayasu, et al., Critical Currents of Nb_3Sn wires of the US-DPC Coil, "CEC-ICMC Conference", Huntsville, June 1991.
4. C.Y. Gung, et al., Comparisons of AC Losses of Nb3Sn Single Strands and US-DPC Conductor, "CEC-ICMC Conference", Huntsville, June 1991.
5. JAERI, Review of US-DPC experiments, in "Proceedings US-DPC test results workshop", ed. J.V. Minervini, MIT PFC, April 1991.

9.3 Estimate of coupling time constant

Section 9.3 outlines the analysis used to calculate the coupling time constant τ_{eff} of the US-DPC wire and presents the results. In section 9.3.1, a description of the model used to find the US-DPC coupling time constant is given. In section 9.3.2, the measured coupling losses found from runs 205 through 207 are used to find the effective coupling time constant of the US-DPC which is then compared with the τ_{eff} value obtained from single wire measurements. Finally, as a check of the analytical model, the coupling losses of the US-DPC trapezoidal-pulse runs are compared to the coupling losses predicted by the analytical model.

9.3.1 Analytical model

Based on the anisotropic continuum model[1] for a twisted superconducting wire with uniformly distributed filaments, the coupling loss in a perpendicular triangular-wave field is written as[2]

$$Q_{c,\text{ramp}}\ [\text{Joule/m}^3 \text{ of wire}] = 2\left(\frac{L}{2\pi}\right)^2 \int_0^{T_m} \frac{\dot{B}^2}{\rho(T,B)}\,dt \qquad (9.9)$$

where L (m) is the wire twist pitch and $\rho(T, B)$ is an effective transverse resistivity as a function of temperature and applied field as shown below.

$$\rho(T,B)\ [\text{ohm-m}] = \kappa\left(\frac{\rho_{0,RT}}{RRR} + \beta B\right) \qquad (9.10)$$

where $\rho_{0,RT}$ is the zero field, room temperature resistivity of the matrix material, B is a scaling factor for magnetoresistivity, RRR is the residual resistivity ratio, and κ is the scaling factor for transverse resistivity expressed as the ratio $(1-\lambda)/(1+\lambda)$ with λ equal to the volume fraction of superconductor. The external field is a linear function of time, $|dB(t)dt| = (B_m - B_0)t/T_m$. The final form of coupling loss in a triangular-wave field can be written as shown in Equation 9.11.

$$Q_{c,ramp} = 2\left(\frac{L}{2\pi}\right)^2 \frac{B_m - B_0}{\beta\, T_m} \ln\left[\frac{\frac{\rho_{0,RT}}{RRR} + \beta\, B_m}{\frac{\rho_{0,RT}}{RRR} + \beta\, B_0}\right] \tag{9.11}$$

where $Q_{c,ramp}$ is in Joule/m^3 of wire.

For the US-DPC chrome-plated wire in the full-size cable, RRR equals 27.

The coupling loss of a superconducting wire in a perpendicular sinusoidal field is expressed as shown in Equation 9.12[2].

$$Q_{c,sinusoidal}\ [\text{Joule/m}^3 \text{ of wire}] = \frac{B_r^2}{2\mu_0} \frac{\pi\omega\tau}{1 + \omega^2\tau^2} \tag{9.12}$$

where B_r(T) is the peak-to-peak value of the applied sinusoidal ripple field and ω is the angular frequency. The coupling time constant at B can be written as shown in Equation 9.13.

$$\tau\ [s] = \tau_{eff} \frac{\rho_L(T = 4.2\text{ K}, B = 0)}{\rho_L(T = 4.2\text{ K}, B)} \tag{9.13}$$

The parameter τ_{eff} is defined as the effective coupling time constant at a bias field set to zero, which is expressed as shown in Equation 9.14.

$$\tau_{eff}\ [s] \equiv \frac{\mu_0}{2\kappa\rho_L(T = 4.2\text{ K}, B = 0)} \left(\frac{L}{2\pi}\right)^2 \tag{9.14}$$

9.3.2 Effective coupling time constant

Three of the US-DPC test results (runs 205 to 207) for double pancake B are used to evaluate the effective coupling time constants. All were single-coil trapezoidal pulses ramped up from 0 kA to 20 kA in 1 s, followed by a flat-top of 13 s, then ramped down to 0 kA in 1 s. In the latter two runs, a sinusoidal waveform field (6.5Hz) was superposed on the flattop for 11 s with peak-to-peak current values of 600 A and 1400 A. The coupling loss due to the sinusoidal ripple was obtained by subtracting the total loss of run 205 from that of either run 206 or 207. With the known coupling loss, the effective coupling time constants of the US-DPC double pancake B were calculated by Equations 9.12 to 9.14.

The results are listed in Table 9.3. The effective coupling time constants of the single-wire coupling losses calculated by the same method are also shown for comparison. Except for Case 2 (Run 207 minus Run 205), all the cases have consistent effective coupling time constants and scaling factors for transverse resistivity. The anomaly of Case 2 is probably due to a local recovered quench which added joule heat to the AC losses, thus increasing the effective coupling time constant.

The experimental coupling losses of double pancake B in single-coil trapezoidal-pulse tests (Fig. 9.23) are obtained by subtracting the extrapolated hysteresis losses from the total losses. The calculated coupling losses using Equation 9.11 are also shown.

Table 9.3 Comparison of effective coupling time constants.

Case	Type of test	Peak-to-peak field of sinusoidal wave	Frequency [Hz]	Bias field	Coupling loss [Joule]	τ_{eff} [ms]	κ
1	US-DPC	Ir = 0.6 kA	6.5	20 kA	285.22	1.66	1.01
2	US-DPC	Ir = 1.4 kA	6.5	20 kA	2660.9	2.86	0.59
3	Single-wire	Br = 0.086 T	7.5	3.37 T	0.00880	1.74	0.96
4	Single-wire	Br = 0.086 T	7.5	4.30 T	0.00868	1.79	0.94

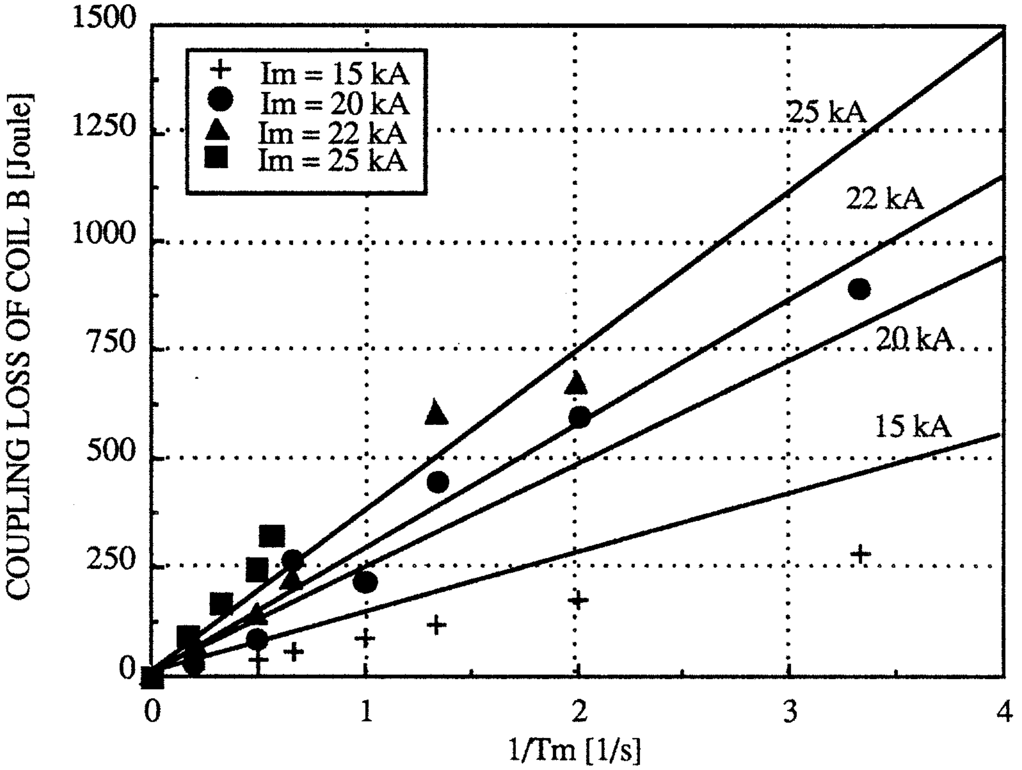


Figure 9.23 - Comparisons of measured coupling losses and the calculated coupling loss from Equation 9.11 for the case of single-trapezoidal pulse fields.

References

1. W.J. Carr, "AC Loss in a Twisted Filamentary Superconducting Wire I," J. Appl. Phys., Vol. 45, No. 2, 1974, p. 929.
2. M.N. Wilson, "Superconducting Magnet", Clarendon Press, Oxford (1986).
3. C. Gung, et al., "Comparisons of AC Losses of Nb3Sn Single Strands and US-DPC Conductor," CEC-ICMC Conference, Huntsville, June 1991.

9.4 Flow choking

During AC testing of the US-DPC, the flow at the inlet of each double pancake was momentarily restricted or "choked" due to the AC loss energy input to the SHe coolant. Figures 9.24 and 9.25 plot the resultant flow reduction at the inlet of double pancake B for specific trapezoidal current pulses. Figure 9.24 plots the flow reduction as a function of flat top current at a constant ramp time of 2.0 seconds, and Figure 9.25 plots the flow reduction as a function of ramp time at a constant flat top current of 20 kA. The trends show that the flow reduction increases as the flattop currents increase and as the ramp times decrease. Table 9.4 lists the current charging parameters and the steady state and minimum flows as well as the resultant flow reduction for the AC test runs plotted in Figures 9.24 and 9.25. Figures 9.26 through 9.35 show the flow measurements and current profiles for the AC test runs plotted in 9.24 and 9.25.

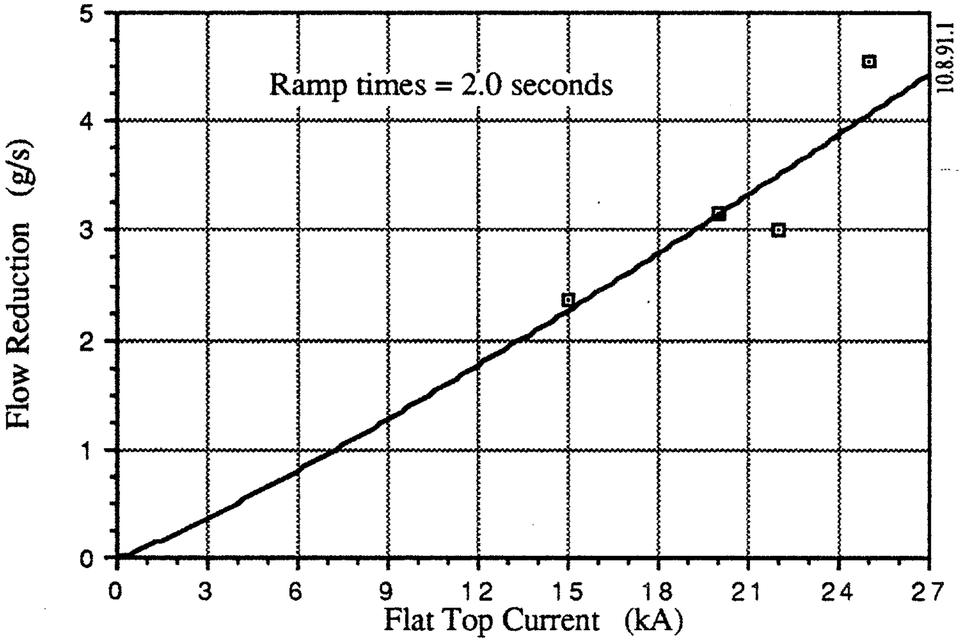


Figure 9.24 - Flow reduction at the inlet of double pancake B as a function of flattop current at constant ramp times of 2.0 seconds. Figures 9.26 through 9.29 show actual flow measurements and current profiles for the runs plotted above.

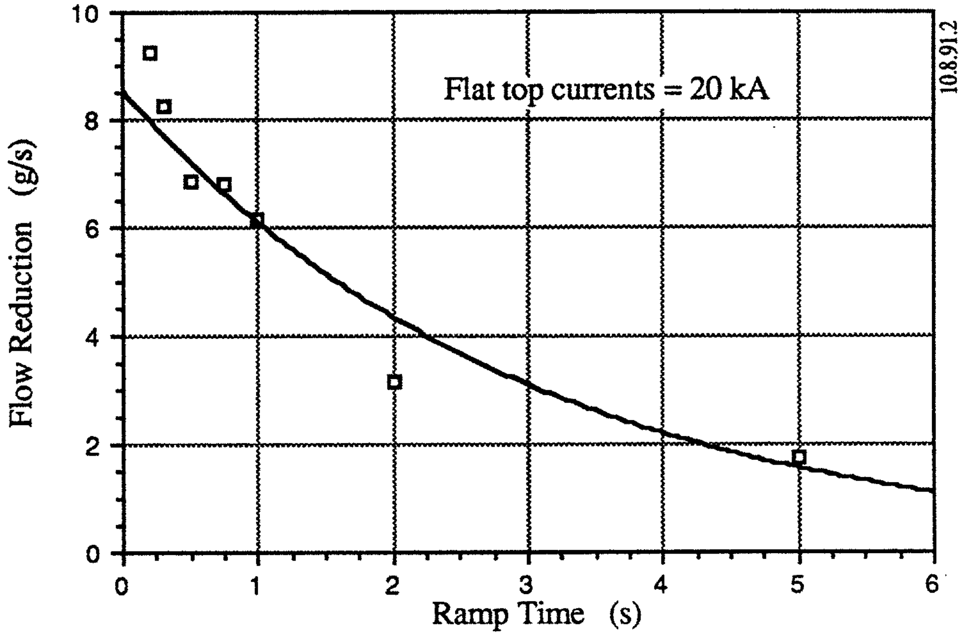


Figure 9.25 - Flow reduction at the inlet of double pancake B as a function of ramp time at constant flattop currents of 20 kA. Figures 9.27 and 9.30 through 9.35 show the actual flow measurements and current profiles for the runs plotted above.

Table 9.4 - Data plotted in figures 9.24 and 9.25 including parameters of the current charging profile and the steady state and minimum flows.

Run No.	Ramp Time (s)	Flat Top Current (kA)	Steady State Flow (g/s)	Minimum Flow (g/s)	Flow Reduction (g/s)	Flow Reduction (%)
102	2.0	15	12.56	10.2	2.36	19
110	2.0	20	12.57	9.4	3.17	25
143	2.0	22	12.41	9.4	3.01	24
120	2.0	25	13.05	8.5	4.55	35
139	0.2	20	13.25	4.0	9.25	70
116	0.3	20	13.07	4.8	8.27	63
115	0.5	20	13.05	6.2	6.86	53
114	0.75	20	13.01	6.2	6.81	52
111	1.0	20	12.63	6.5	6.13	49
109	5.0	20	12.57	10.8	1.77	14

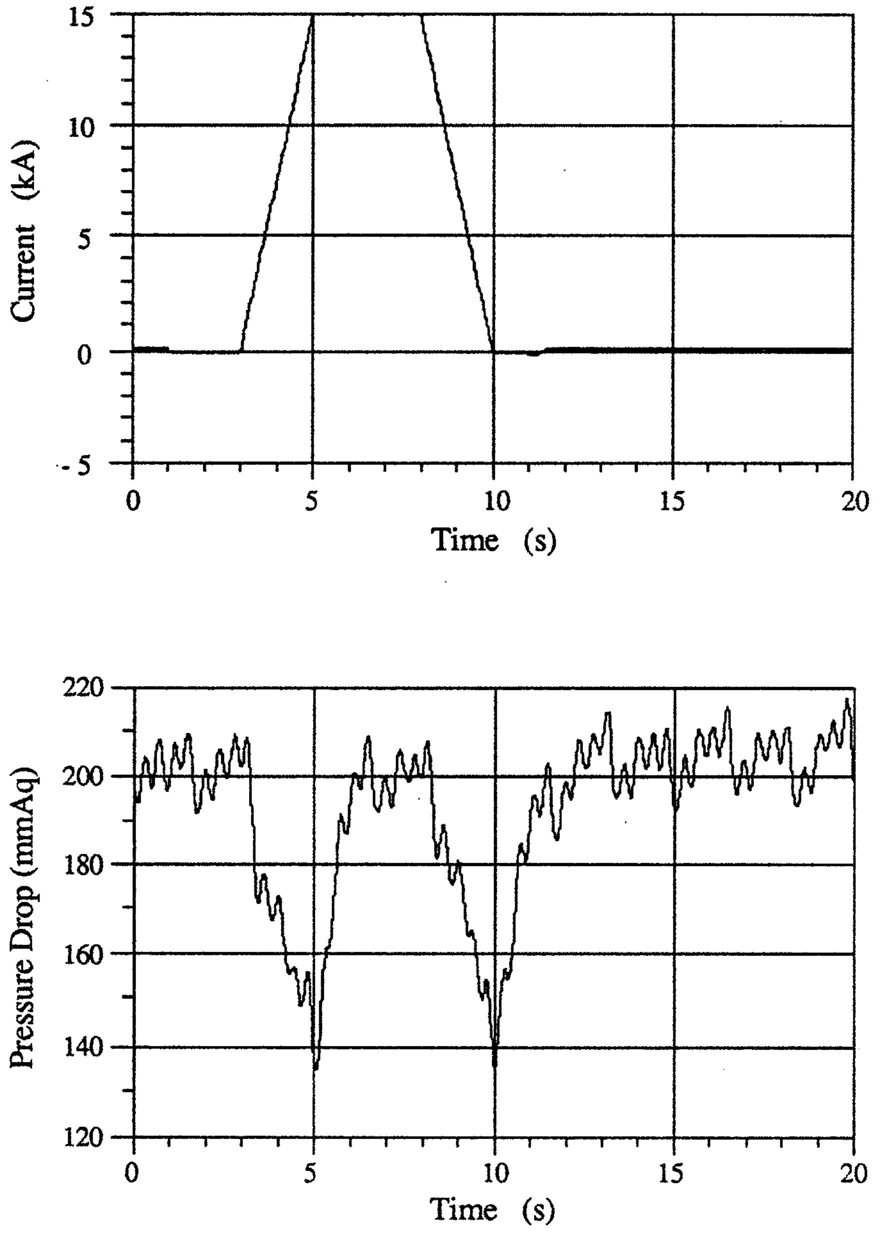


Figure 9.26 - Flow choking in run number 102 . Flow is temporarily reduced or "choked" from its steady state value of 12.56 g/s to a minimum of 10.2 g/s during ramps. The current pulse and flow reaction have the same zero times. Conversion from pressure drop to mass flow is given by the following equation where ρ is approximately 0.140 g/cm^3.

$$\dot{m}\ (g/s) = 2.36 \sqrt{\rho\ (g/cm^3) \times \Delta P\ (mmAq)}$$

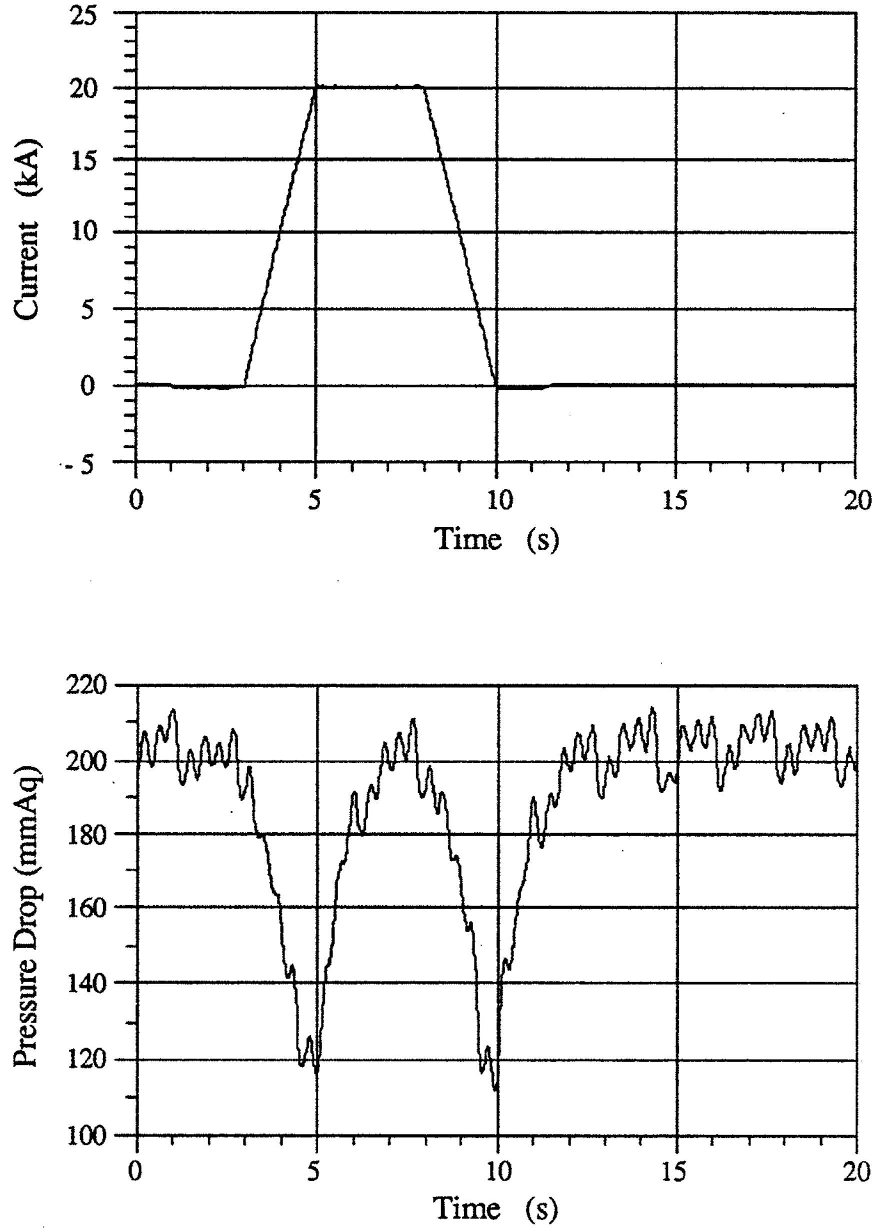
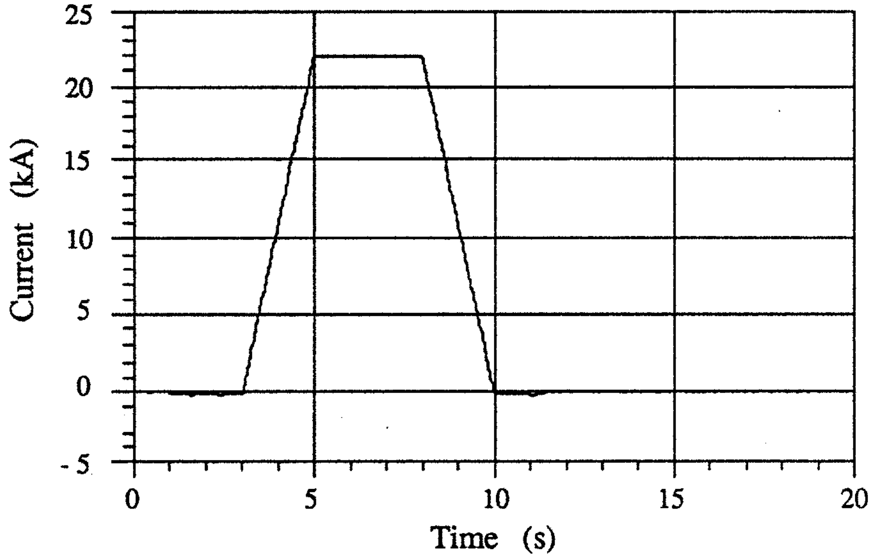


Figure 9.27 - Flow choking in run number 110. Flow is temporarily reduced or "choked" from its steady state value of 12.57 g/s to a minimum of 9.4 g/s during ramps. The current pulse and flow reaction have the same zero times. Conversion from pressure drop to mass flow is given by the following equation where ρ is approximately 0.140 g/cm^3.

$$\dot{m}\ (\mathrm{g/s}) = 2.36\sqrt{\rho\ (\mathrm{g/cm^3}) \times \Delta P\ (\mathrm{mmAq})}$$



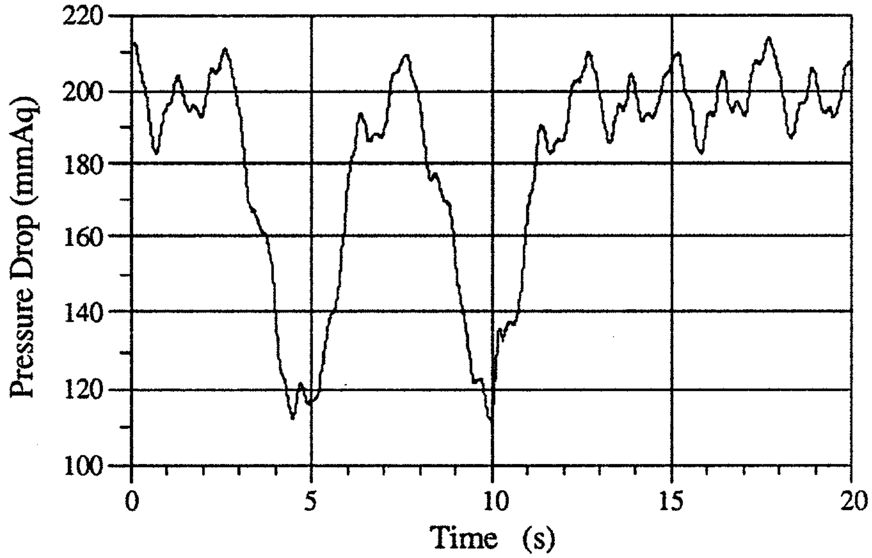


Figure 9.28 - Flow choking in run number 143 . Flow is temporarily reduced or "choked" from its steady state value of 12.41 g/s to a minimum of 9.4 g/s during ramps. The current pulse and flow reaction have the same zero times. Conversion from pressure drop to mass flow is given by the following equation where ρ is approximately 0.140 g/cm^3.

$$\dot{m}\ (g/s) = 2.36 \sqrt{\rho\ (g/cm^3) \times \Delta P\ (mmAq)}$$

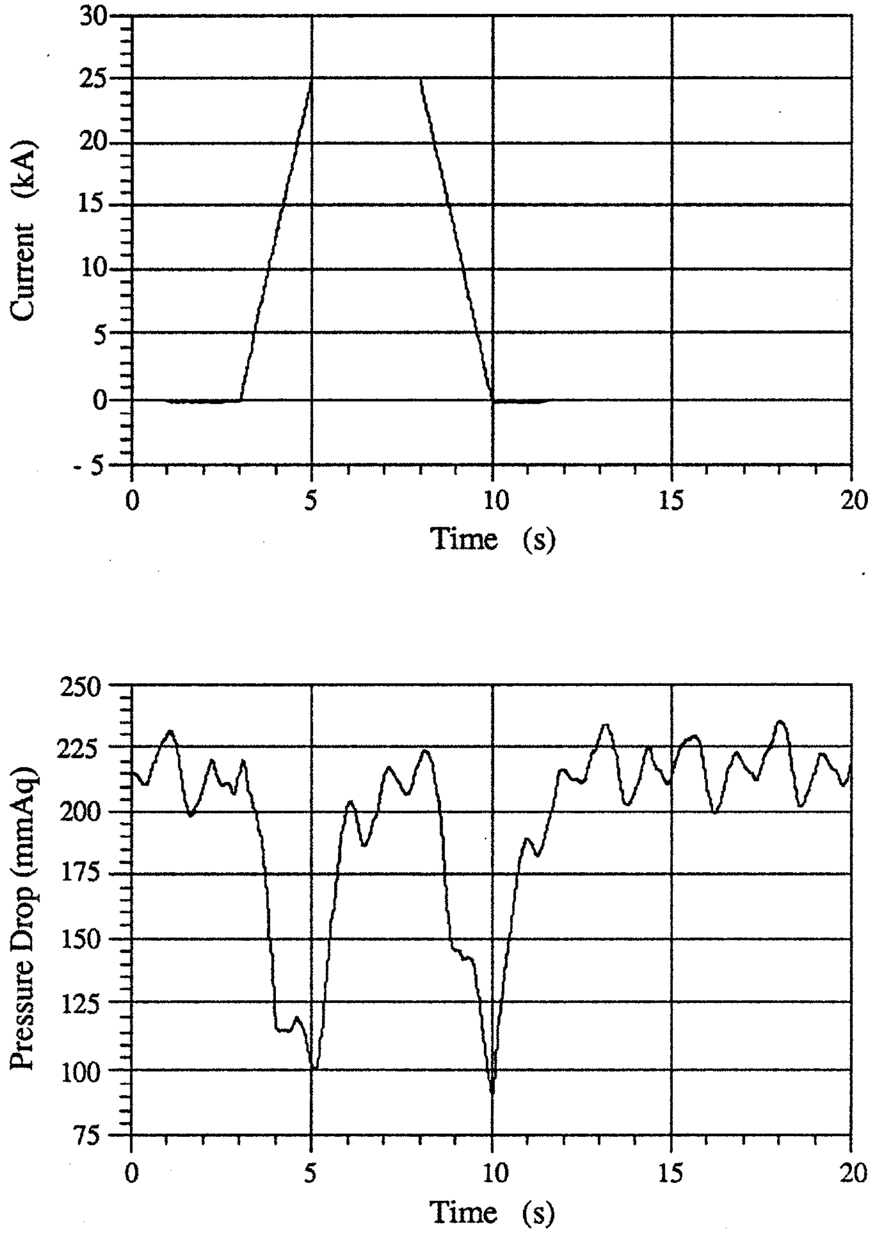


Figure 9.29 - Flow choking in run number 120 . Flow is temporarily reduced or "choked" from its steady state value of 13.05 g/s to a minimum of 8.5 g/s during ramps. The current pulse and flow reaction have the same zero times. Conversion from pressure drop to mass flow is given by the following equation where ρ is approximately 0.140 g/cm^3.

$$\dot{m}\ (\mathrm{g/s}) = 2.36\sqrt{\rho\ (\mathrm{g/cm^3}) \times \Delta P\ (\mathrm{mmAq})}$$

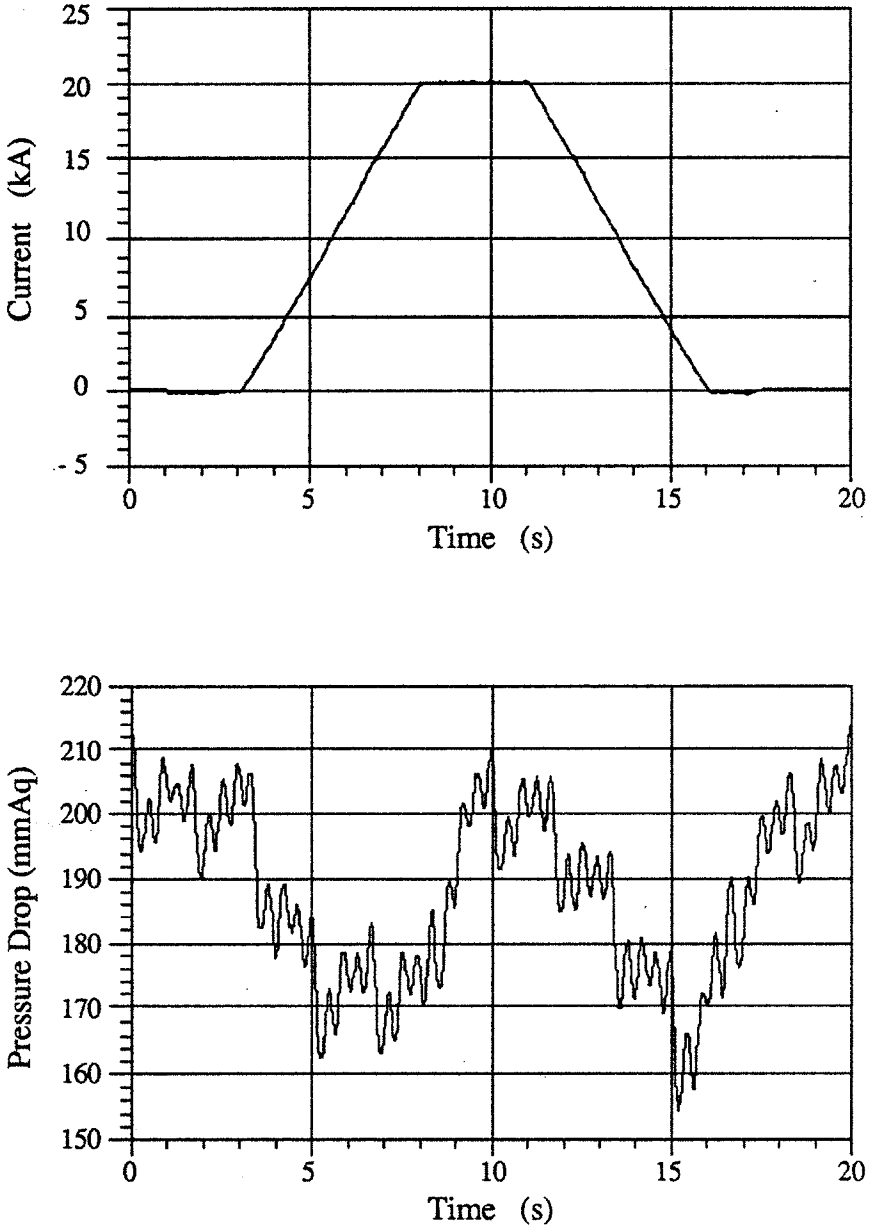


Figure 9.30 - Flow choking in run number 109 . Flow is temporarily reduced or "choked" from its steady state value of 12.57 g/s to a minimum of 10.8 g/s during ramps. The current pulse and flow reaction have the same zero times. Conversion from pressure drop to mass flow is given by the following equation where ρ is approximately 0.140 g/cm^3.

$$\dot{m}\ (\mathrm{g/s}) = 2.36 \sqrt{\rho\ (\mathrm{g/cm^3}) \times \Delta P\ (\mathrm{mmAq})}$$

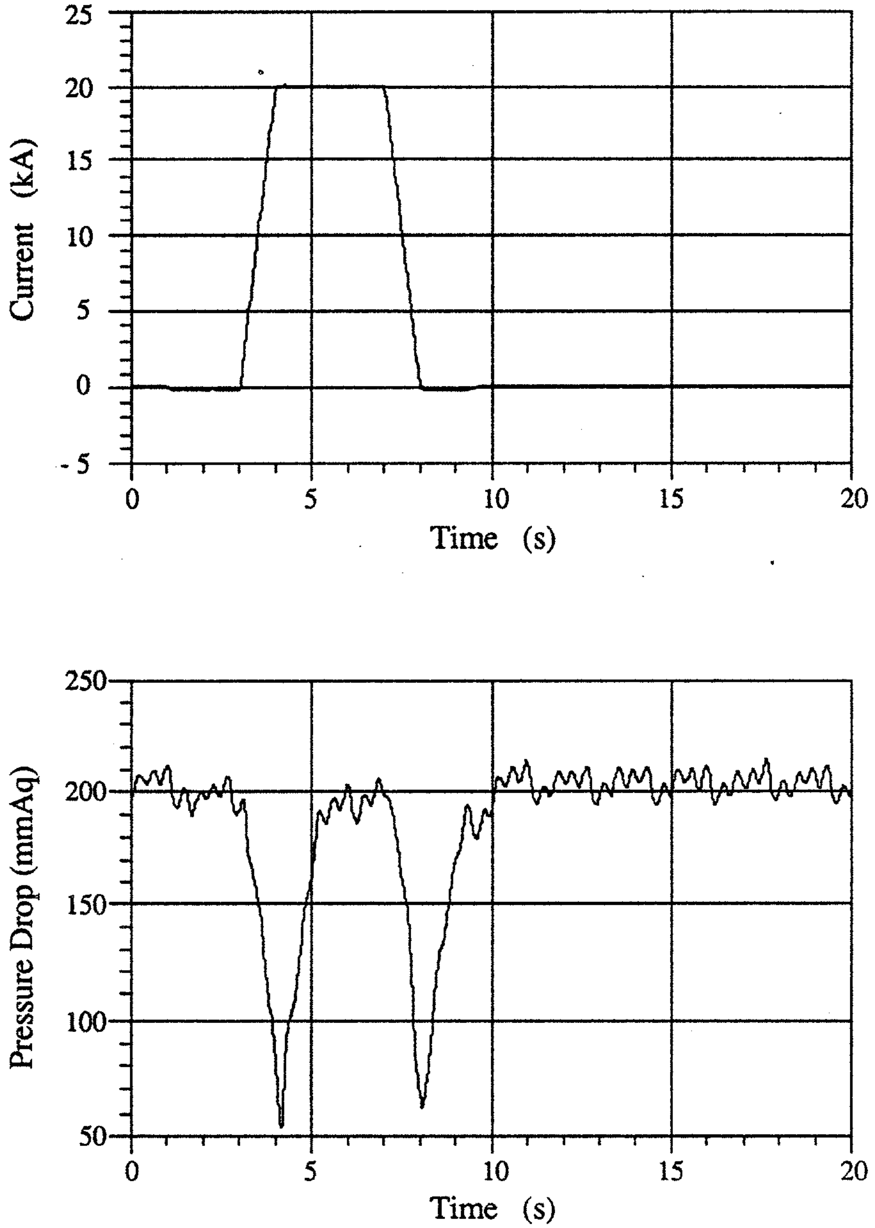
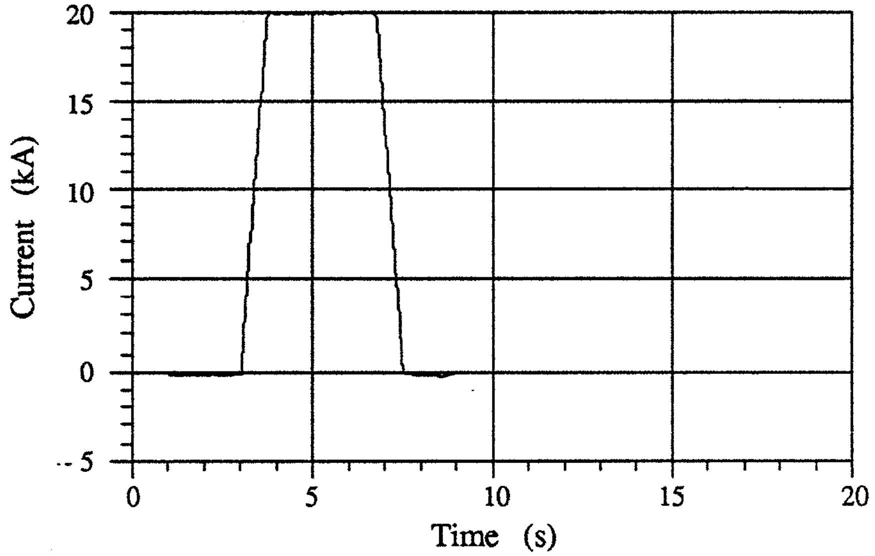


Figure 9.31 - Flow choking in run number 111 . Flow is temporarily reduced or "choked" from its steady state value of 12.63 g/s to a minimum of 6.5 g/s during ramps. The current pulse and flow reaction have the same zero times. Conversion from pressure drop to mass flow is given by the following equation where ρ is approximately 0.140 g/cm^3.

$$\dot{m}\ (\mathrm{g/s}) = 2.36\sqrt{\rho\ (\mathrm{g/cm^3}) \times \Delta P\ (\mathrm{mmAq})}$$



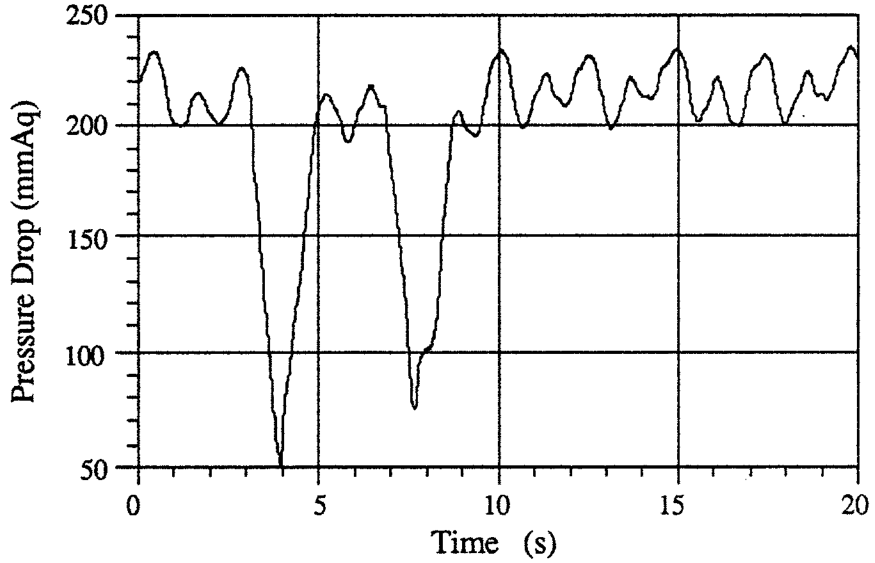


Figure 9.32 - Flow choking in run number 114 . Flow is temporarily reduced or "choked" from its steady state value of 13.01 g/s to a minimum of 6.2 g/s during ramps. The current pulse and flow reaction have the same zero times. Conversion from pressure drop to mass flow is given by the following equation where ρ is approximately 0.140 g/cm^3.

$$\dot{m}\ (g/s) = 2.36\sqrt{\rho\ (g/cm^3) \times \Delta P\ (mmAq)}$$

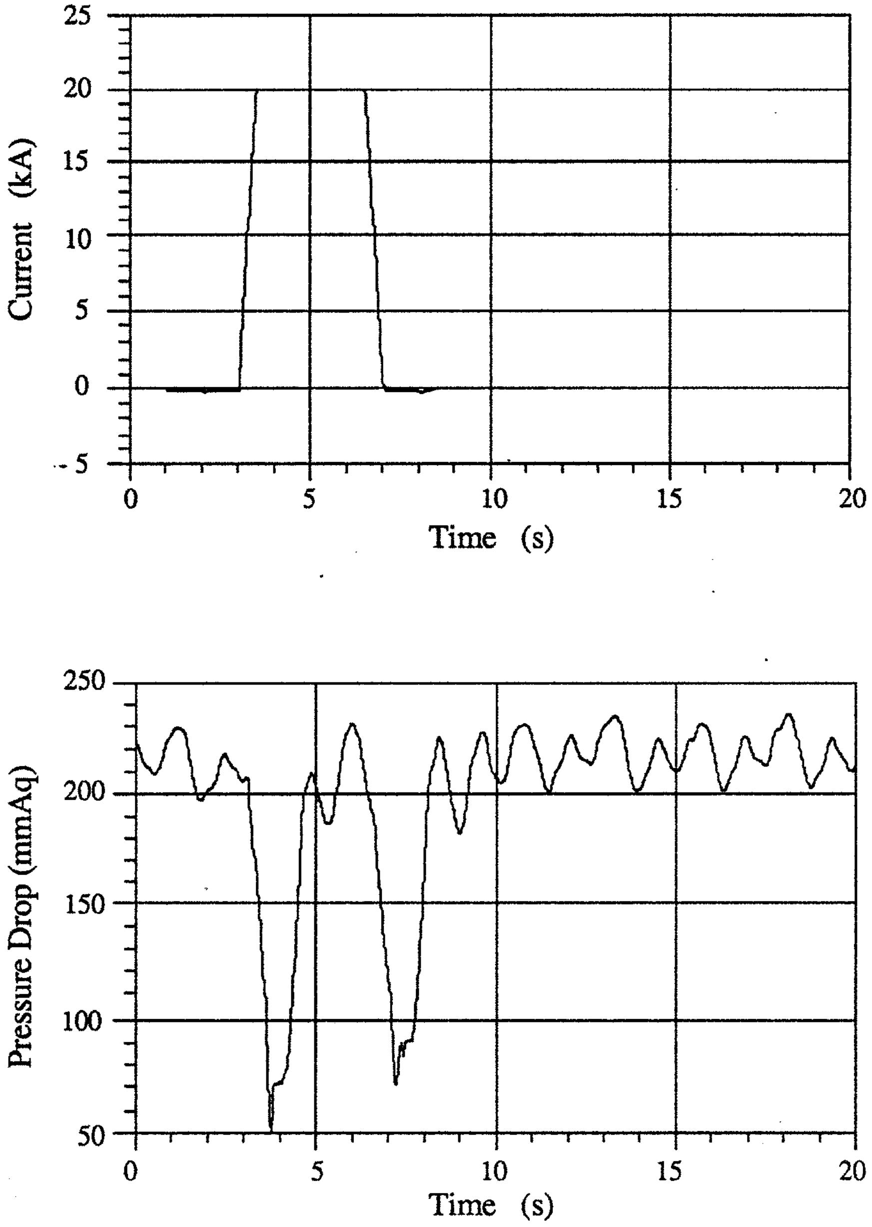
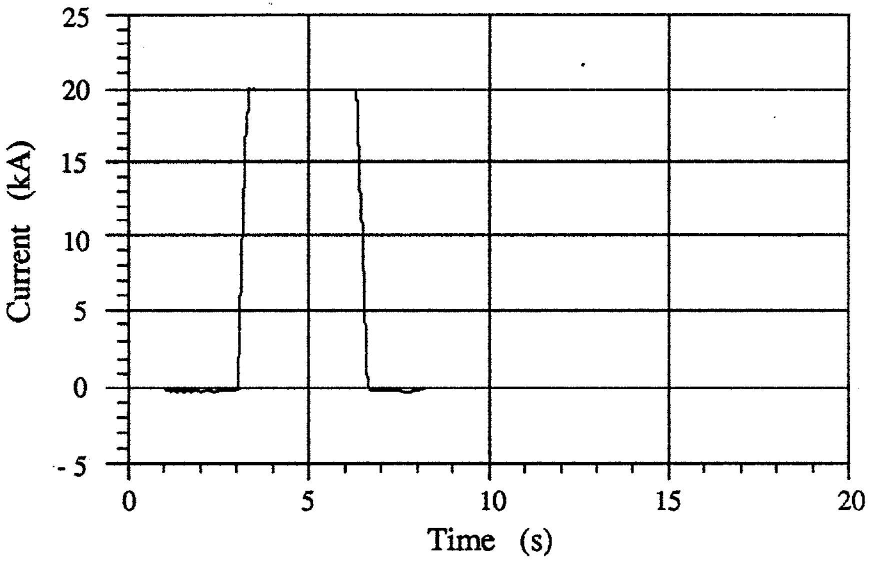


Figure 9.33 - Flow choking in run number 115. Flow is temporarily reduced or "choked" from its steady state value of 13.05 g/s to a minimum of 6.2 g/s during ramps. The current pulse and flow reaction have the same zero times. Conversion from pressure drop to mass flow is given by the following equation where r is approximately 0.140 g/cm3.

$$\dot{m}\ (\mathrm{g/s}) = 2.36 \sqrt{\rho\ (\mathrm{g/cm^3}) \times \Delta P\ (\mathrm{mmAq})}$$



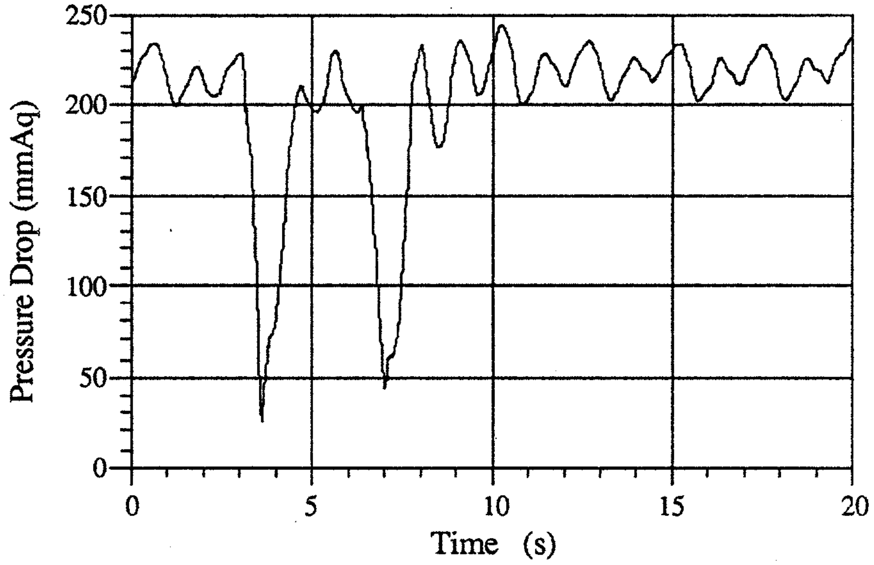


Figure 9.34 - Flow choking in run number 116. Flow is temporarily reduced or "choked" from its steady state value of 13.07 g/s to a minimum of 4.8 g/s during ramps. The current pulse and flow reaction have the same zero times. Conversion from pressure drop to mass flow is given by the following equation where r is approximately 0.140 g/cm3.

$$\dot{m}\ (\mathrm{g/s}) = 2.36\sqrt{\rho\ (\mathrm{g/cm^3})\ \mathrm{x}\ \Delta P\ (\mathrm{mmAq})}$$

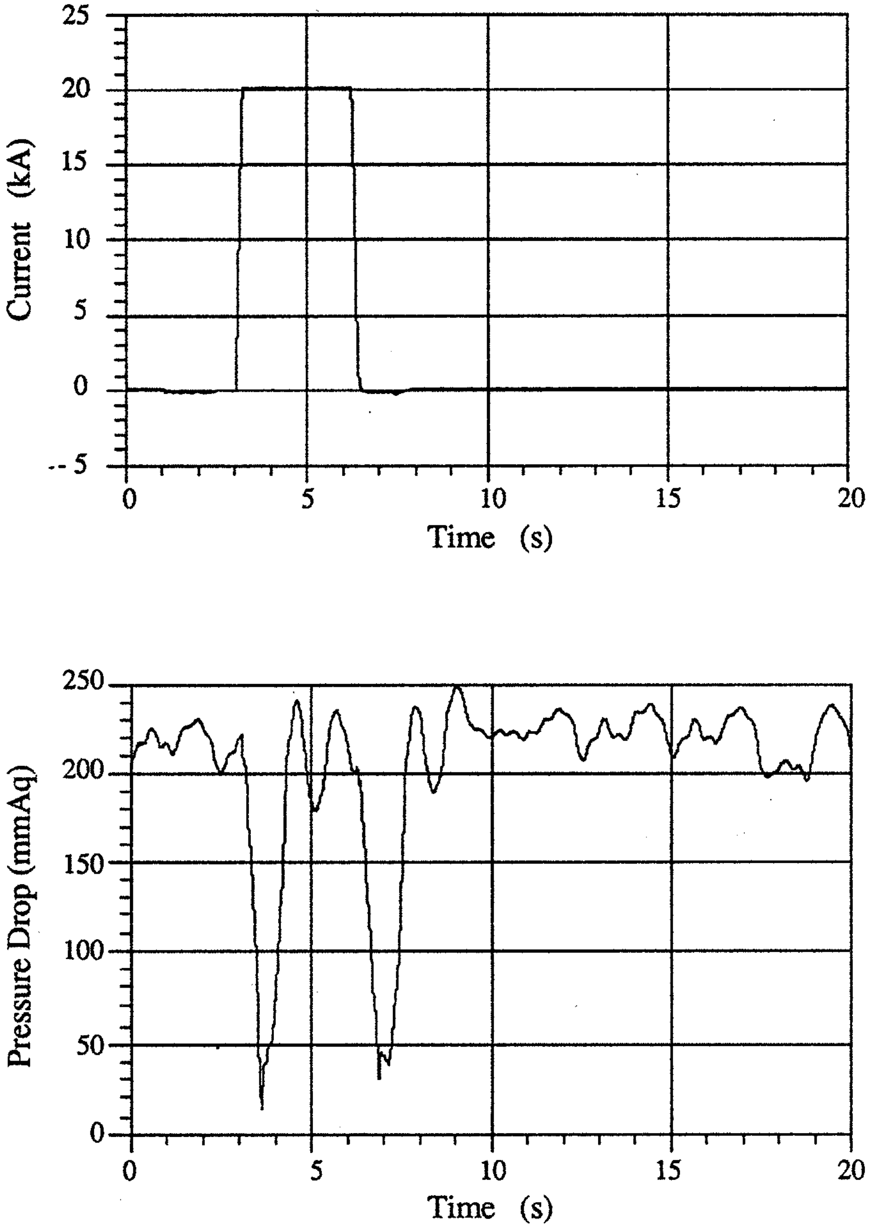


Figure 9.35 - Flow choking in run number 139. Flow is temporarily reduced or "choked" from its steady state value of 13.25 g/s to a minimum of 4.0 g/s during ramps. The current pulse and flow reaction have the same zero times. Conversion from pressure drop to mass flow is given by the following equation where r is approximately 0.140 g/cm3.

$$\dot{m}\ (\mathrm{g/s}) = 2.36\sqrt{\rho\ (\mathrm{g/cm^3}) \times \Delta P\ (\mathrm{mmAq})}$$

10. Ramp-rate limitation

During AC testing, a ramp-rate limitation was discovered. In order to show the behavior of the limitation, the following chapter presents comparisons of the current versus ramp time data of various groupings of runs. First, section 10.1 presents three classifications by which each run is characterized to provide sensible comparisons of the data. Next, section 10.2 presents for each quenched run, the initiation point and time of quench, quench and flattop current, ramp time, detection system delay time, and run classifications. Also, a typical crossover-turn voltage rise during quench is shown. Section 10.3 compares various groupings of test runs to reveal the ramp-rate limitation behavior. Finally, section 10.4 presents an argument for using the limiting current as a means of predicting the ramp-rate limitation

10.1 Characterization of an AC test run

The US-DPC data contain 205 AC test runs (runs 74 - 278) each of which are characterized by the following classifications.

10.1.1 Quenched or non-quenched

There are 51 quenched runs and 154 non-quenched runs. The 51 quenches can be further classified according to their initiation point.

> Crossover Turn -- Connects the upper and lower pancake at the inner diameter and experiences the highest field of any turn in the double pancake.
>
> Interpancake Lap Joint -- Connects the double pancakes at the outer diameter and experiences low fields.
>
> Middle Turns -- Wound outwardly from the crossover turn and terminate at either the interpancake lap joints or the current leads. Voltage taps were not attached on individual turns through the middle of the double pancakes, so the exact point of normal-zone initiation could not be pinpointed in this region.

10.1.2 Test mode (single-coil or series-coil)

There are 180 single-coil and 25 series-coil test runs. The single-coil test runs were performed by charging only the US-DPC with no contribution from the background field coils, U1 and U2. The series-coil test runs were performed by charging the US-DPC in an electrical series connection with the background field coils.

10.1.3 Charging waveform

Six different charging waveforms and combinations thereof were employed: triangular, trapezoidal, round-edge trapezoidal, rippled trapezoidal, and two-step trapezoidal. For a schematic of each waveform refer to Figure 9.2.

10.2 The quenched runs

The lap joint and middle turn quenches could not be included in most of the analysis due to the placement of voltage taps for digital records. Nevertheless, the following questions were answered, where possible, for each quench:

1. Where did the quench initiate?
2. What was the average time of initiation of trapezoidal-pulse quenches?
3. Of all the quenches, what percentage initiated before onset of the flattop current?
4. What was the current at the time of initiation for before-flattop quenches?
5. Were there any unusual data that reveal the cause of the ramp-rate limitation?
6. What was the delay time of the quench detection system?
7. What was the rise in voltage across the crossover turn normal zone?

Table 10.1 and Figures 10.1 and 10.2 list and plot the quench data. Note that all of the middle-turn quenches occurring during the series-coil tests showed a voltage rise in the crossover turn, and it is believed that the initiation point was close to the crossover turn for these runs. The sole middle-turn quench occurring during the single-coil tests (run 237) did not show a voltage rise in the crossover turn.

From the data in Table 10.1 and Figures 10.1 and 10.2, the answers to the above questions are as follows:

1. Where did the quench initiate?

   Of the 51 quenches, 34 (66.7%) initiated in the crossover turn of double pancake C. Note that the highest field in the US-DPC occurs in the crossover turn of double pancake B, which would therefore be the expected point of normal zone initiation. The only difference in the geometry of double pancake C is the absence of a heater wire through the cable center, resulting in a larger void fraction. For a further breakdown of the quenched runs according to their initiation point, see Table 10.2

   Another interesting note is that of the seven quenches occurring during the series-coil tests, six (86%) initiated in the middle-turns, and just one initiated in the crossover turns.

Table 10.2 - Breakdown of the 51 quenches according to their initiation point.

initiation point	number	overall percentage
crossover turn of double pancake C	34	66.7
interpancake lap joints	7	13.7
middle turns of double pancake C	5	9.8
crossover turns of double pancakes B and C	2	3.9
middle turns of double pancake B	1	2.0
middle turns of double pancakes A, B, and C	1	2.0
no data due to a mistrigger of the detection system	1	2.0

Table 10.1 - A complete listing of data from the 51 quenched runs of the US-DPC.

run no.	quench initiation point	quench initiation time t_q (s)	ramp time t_m (s)	before or after flattop?	t_q / t_m	dump time t_{dump} (s)	quench current I_q (kA)	I_q / I_m	charging profile	comments
94	C crossover	0.90	1.0	before	0.90	1.31	27.3	0.910	triangle	t = 0 at the beginning of the current pulse for
95	C crossover	0.93	1.0	before	0.93	1.34	27.1	0.934	triangle	all runs
99	joint	-----	0.54	-----	-----	2.15	24.0	1.00	trpzd	Mass flow to joint too low
121	C crossover	1.58	1.53	after	1.033	2.16	25.0	1.00	trpzd	
125	C crossover	5.86	6.01	before	0.975	6.30	29.5	0.983	trpzd	
126	C crossover	6.85	7.01	before	0.977	7.30	29.3	0.977	trpzd	
129	C crossover	1.10	1.03	after	1.068	1.71	24.0	1.00	trpzd	
130	C crossover	1.30	1.03	after	1.262	1.99	23.0	1.00	trpzd	
133	C crossover	1.13	1.02	after	1.108	1.82	24.0	1.00	trpzd	
135	C crossover	4.04	3.96	after	1.020	4.55	27.5	1.00	trpzd	
147	joint	-----	0.35	-----	-----	2.31	22.0	1.00	trpzd	
148	joint	-----	0.24	-----	-----	2.55	21.0	1.00	trpzd	
152	C crossover	1.97	0.75, 0.32	before	0.961*	2.31	28.3	0.943	2-step trpzd	intermediate flattop time = 0.98 s
153	B and C crossover	B-4.07,C-4.04	0.76, 0.31	after	1.000*	B-4.34,C-4.29	B-30, C-30	1.00	2-step trpzd	intermediate flattop time = 2.97 s
154	B and C crossover	B-4.45,C-4.42	0.77, 0.77	before	0.982*	B-4.87,C-4.88	B-29.7,C-29.3	0.977	2-step trpzd	intermediate flattop time = 2.96 s
156	C crossover	4.56	4.50	after	1.013	5.02	28.0	1.00	trpzd	
159	C crossover	6.61	6.5	after	1.017	7.12	29.0	1.00	trpzd	Double and triple trapezoids have nominal 3 s
161	C crossover	7.16	7.04	after	1.017	7.65	29.0	1.00	trpzd	flattops with 0.5 s downramps. Quadruple
165	joint	-----	0.52, 0.51	-----	-----	6.20	22.0	1.00	dble trpzd	trapezoid has nominal 2 s flattops with 0.5
168	joint	-----	0.52,0.49,0.49	-----	-----	11.47	20.0	1.00	triple trpzd	sec downramps.
173	joint	-----	0.5,0.58,0.48,0.6	-----	-----	-----	18.0	1.00	quad. trpzd	
181	C crossover	1.78	-----	before	-----	2.26	26.7	0.89	round-edge	Possible non-propagating quench in B
182	C crossover	7.98	8.0	before	0.998	8.42	29.3	0.993	trpzd	
186	C crossover	7.22	7.51	before	0.961	7.71	29.4	0.964	trpzd	
189	C crossover	7.58	8.0	before	0.948	8.09	29.2	0.942	trpzd	
191	C crossover	8.26	-----	before	-----	8.73	29.3	0.916	trpzd	
193	C crossover	9.95	9.93	after	1.002	10.3	33.0	1.00	trpzd	
201	C crossover	1.09	1.03	after	1.058	1.51	23.0	1.00	trpzd	Possible non-propagating quench in B
203	C crossover	1.09	1.01	after	1.079	1.59	23.0	1.00	trpzd	Possible non-propagating quench in B
209	C crossover	1.09	1.01	after	1.079	1.64	24.0	1.00	trpzd	
217	C crossover	7.86	3.32, 1.71	before	0.979*	8.34	29.1	0.970	2-step trpzd	intermediate flattop time = 3.00 s
218	C crossover	7.96	3.69, 1.34	before	0.990*	8.42	29.5	0.983	2-step trpzd	intermediate flattop time = 3.01 s
220	C crossover	2.91	1.01, 1.01	before	0.970*	3.42	29.3	0.977	2-step trpzd	intermediate flattop time = 0.98 s
223	C crossover	3.64	1.0, 1.57	after	1.017*	4.17	29.0	1.00	2-step trpzd	intermediate flattop time = 1.01 s
226	DATA NOT	RECORDED	PROPERLY,	-----	-----	MISTRIGGER.	------ DATA	NOT	RECORD	ED PROPERLY ----------- MISTRIGGER.
232	joint	-----	1.004	-----	-----	3.66	25.0	1.00	trpzd	Mass flow to joint too low (?)
234	C crossover	1.58	1.52	after	1.039	1.95	26.0	1.00	trpzd	Unusual voltages in C before final quench
237	B middle turns	-----	1.5	-----	-----	1.9	-----	-----	rippled	No evidence of crossover-turn voltage rise.
238	C crossover	6.81	6.97	before	0.977	7.25	28.1	0.937	trpzd	
239	C crossover	7.75	7.95	before	0.975	8.15	29.2	0.973	trpzd	
240	C crossover	8.73	8.96	before	0.974	9.17	29.2	0.973	trpzd	
245	C crossover	6.81	7.02	before	0.970	7.18	29.2	0.973	rippled	All values difficult to read due to ripples.
252	C crossover	5.71	-----	before	-----	6.02	28.9	0.963	rippled	All values difficult to read due to ripples.
253	C crossover	5.59	-----	before	-----	6.02	28.7	-----	rippled	
260	C middle turns	-----	0.78	-----	-----	-----	-----	-----	triangle	
263	C middle turns	-----	1.12	-----	-----	-----	-----	-----	trpzd	After run 253, the series-coil tests begin.
264	C middle turns	-----	1.12	-----	-----	1.54	-----	-----	trpzd	
266	A,B,& C middle	-----	0.89	-----	-----	-----	-----	-----	trpzd	The six middle-turn quenches in the series-coil
275	C middle turns	-----	1.1	-----	-----	1.21	-----	-----	round-edge	tests showed voltage rises in the crossover
276	C crossover	1.23	1.11	after	1.108	1.53	22.0	1.00	trpzd	turns as well.
278	C middle turns	-----	1.1	-----	-----	1.4	-----	-----	trpzd	

* For the two-step trapezoidal waveform, the t_q / t_m calculation defines t_m as the summation of the initial upramp, the final upramp, and the intermediate flattop.

2. What was the average time of initiation of trapezoidal-pulse quenches?
   The quench initiation time t_q is listed in column three of Table 10.1. Of the 22 trapezoidal-pulse quenches for which both the quench initiation time and ramp time could be determined, the average initiation time exceeded the ramp time t_m by 3.1%. The standard deviation of ratios of (t_q / t_m) is 6.8%.

$$(t_q / t_m)_{\text{average}} = 1.031$$

3. Of all the quenches, what percentage initiated before onset of the flattop current?
   Of the 36 quenches for which both the quench initiation time and ramp time could be determined, 20 (55.6%) initiated before and 16 (44.4%) initiated after the onset of the flattop current.

4. What was the current at the time of initiation for before-flattop quenches?
   Of the eighteen before-flattop quenches for which both the quench and flattop current could be determined, the average quench current was 96.0% of the flattop current.

5. Were there any unusual data that reveal the cause of the ramp-rate limitation?
   No conclusions could be drawn as to the cause of the ramp-rate limitation.

6. What was the delay time of the quench detection system?
   Of the 36 quenches for which the delay time could be determined, the average delay was 0.46 seconds with a maximum of 0.69 seconds and minimum of 0.25 seconds. The delay time is defined as the dump time t_{dump} (column 7 in Table 10.1) minus t_q and is plotted in Figure 10.1 as a function of run number. Figure 10.3 shows dump and quench times as measured from a typical crossover turn voltage trace.

7. What was the rise in voltage across the crossover turn normal zone?
   Of the 36 quenches for which the voltage rise ΔV could be measured, the average rise was 1.77 volts with a maximum of 2.89 volts and a minimum of 0.33 volts. ΔV is defined as the total increase in voltage of the crossover turn before the coil dump and is plotted in Figure 10.2 as a function of run number. Figure 10.3 shows ΔV as it was measured from a typical crossover turn voltage trace. Note that the voltage trace has a spike at the time of dump. This spike was present in all the quench voltages and was not included in the measurement of ΔV.

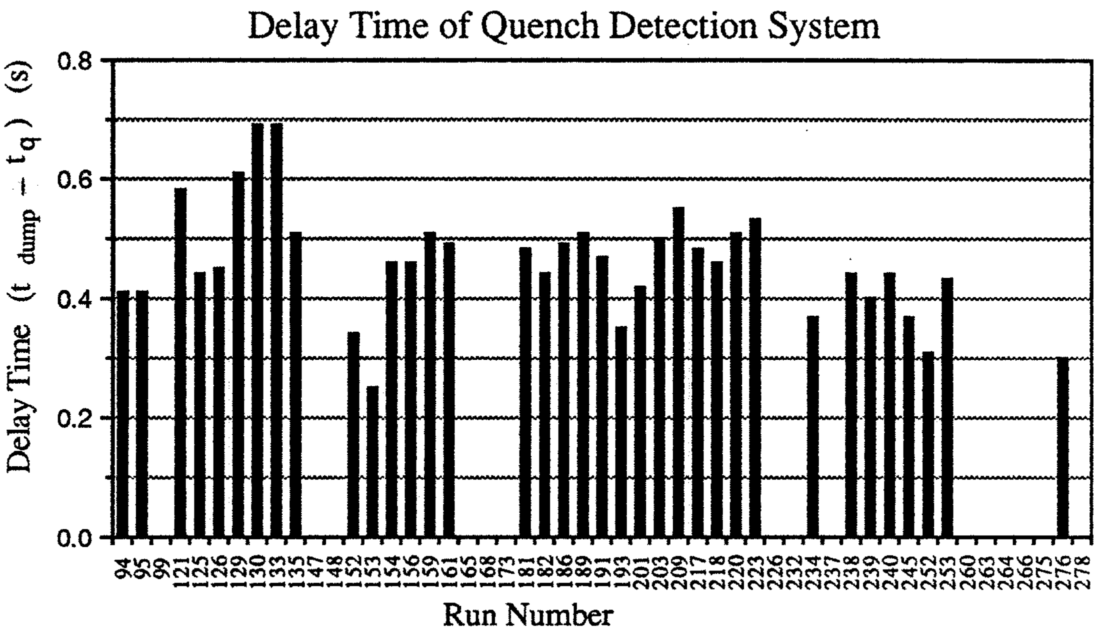


Figure 10.1 - Delay time of the JAERI quench detection system as a function of run number. Delay time is defined as dump time t_{dump} minus quench initiation time t_q (see Figure 10.3). For a description of the power supply and detection system at JAERI see reference 1.

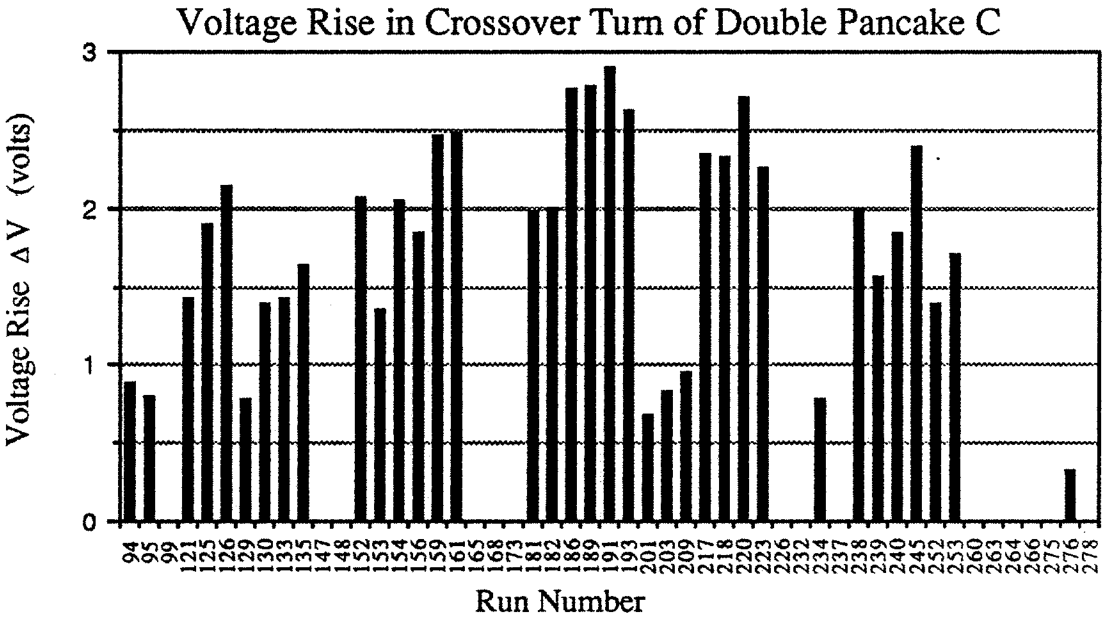


Figure 10.2 - Voltage rise ΔV in the crossover turn of double pancake C as a function of run number. ΔV is defined as the total increase in voltage of the crossover turn before the coil dump (see Figure 10.3).

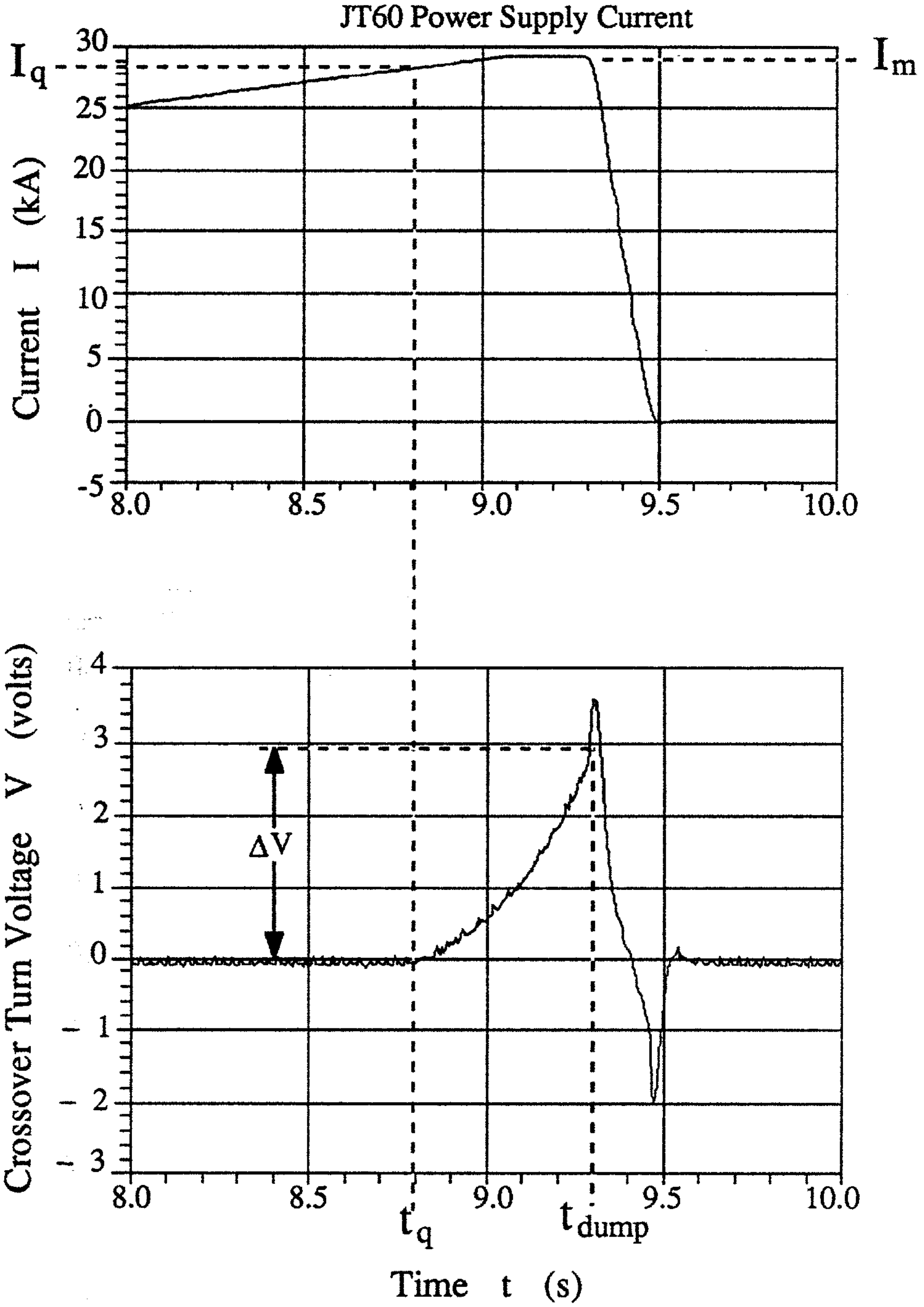


Figure 10.3 - The voltage trace in the crossover turn of double pancake C during the quench of run 186 shows a typical measurement of quench time and current t_q and I_q, dump time t_{dump}, voltage rise ΔV, and flattop current I_m. The current ramp for this run begins at t = 1.58 s, and the current must be divided by 0.951 to compensate for instrumentation error.

10.3 Behavior

In order to show the behavior of the ramp-rate limitation, a baseline limit is used to compare the current versus ramp-time data of various groupings of test runs. Section 10.3.1 establishes the baseline limit, which is then compared with the ramp data from subgroupings of single-coil and series-coil test runs in sections 10.3.2 and 10.3.3, respectively.

10.3.1 Baseline limit

The baseline limit is a linear curve fit of the current versus ramp-time data for crossover turn quenches produced in the single-coil test mode by single trapezoidal waveforms as shown in Figure 10.4 and described by Equation 10.1.

$$I = 23.2 + 0.845\ t \qquad (10.1)$$

where: t in seconds is either time to quench t_q or ramp time t_m
I in kA is either quench current I_q or flattop current I_m

Note that when the normal zone voltage began before onset of the flattop current, the quench current and time to quench data were plotted, and when the normal zone voltage began after onset of the flattop current, the flattop current and ramp time were plotted.

The standard deviation of the baseline limit is 0.878 kA, which corresponds to 3.7% of the predicted current at one second ramp times and 2.8% of the predicted current at 10 second ramp times.

Figure 10.5 compares the non-quenched, single-coil, trapezoidal-pulse runs with the baseline limit to highlight the effect of the ramp-rate limitation.

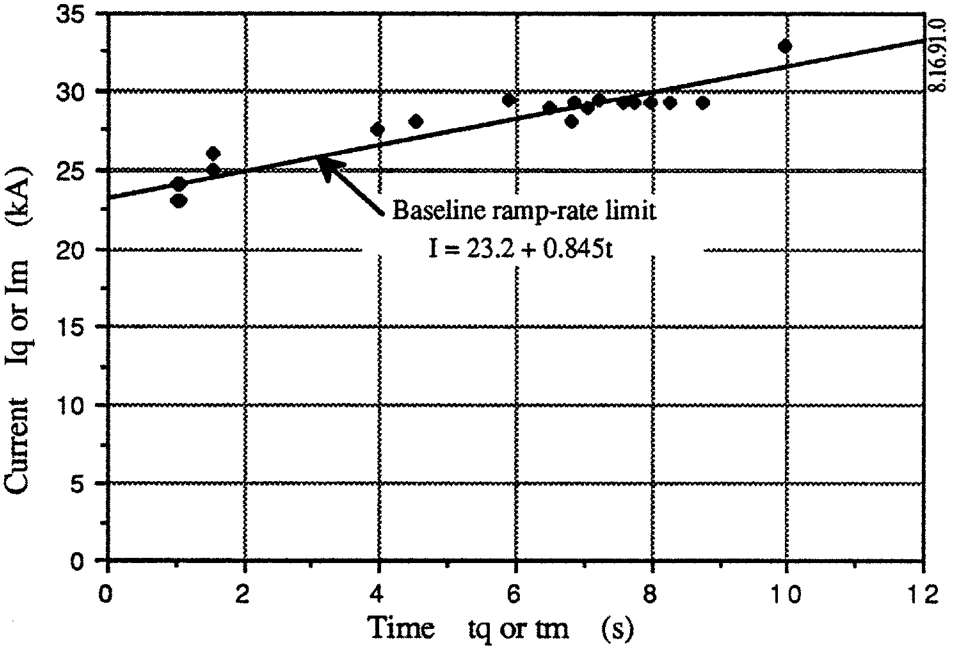


Figure 10.4 - Linear curve fit of single-coil, trapezoidal-pulse, current-versus-time quench data used to define a baseline ramp-rate limit. The limit is compared with various groupings of AC test runs.

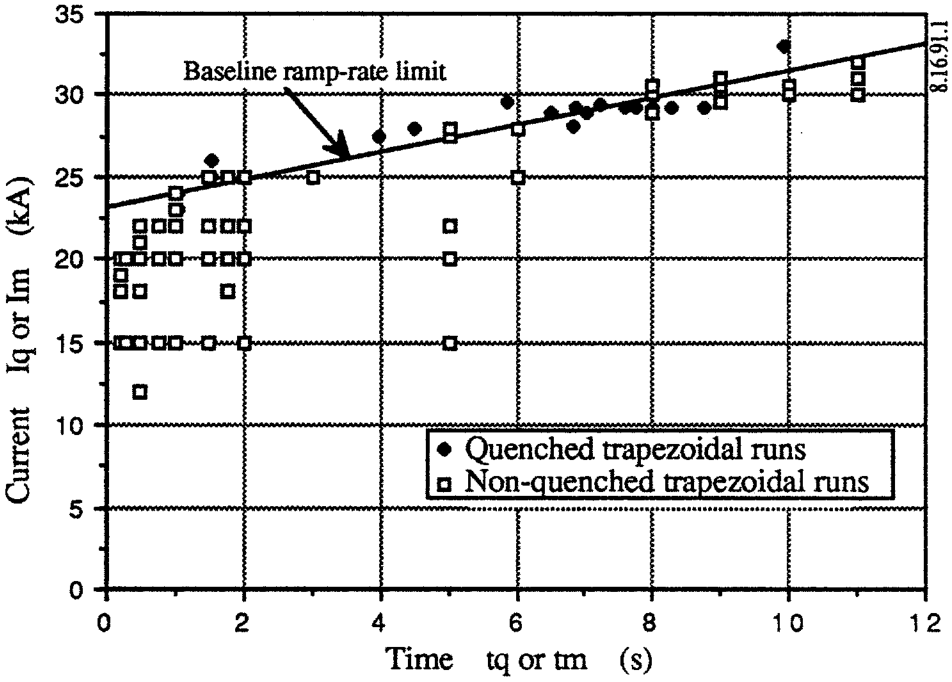


Figure 10.5 - Comparison of the baseline ramp-rate limit to non-quenched trapezoidal-pulse data. Attempts to charge beyond the limit resulted in quenches of the US-DPC.

10.3.2 Single-coil tests

In order to form sensible comparisons with the baseline ramp-rate limit, the single-coil test runs were separated into subgroups of runs quenched in the interpancake lap joints, runs pulsed by triangular waveforms, runs pulsed by round-edge trapezoidal waveforms, runs pulsed by rippled trapezoidal waveforms, and runs pulsed by two-step trapezoidal waveforms in sections 10.3.2.1 - 10.3.2.5, respectively.

10.3.2.1 Runs quenched in the interpancake lap joints

Of the seven interpancake lap joint quenches, all occurred at nominal ramp times of one second or less, and five of the seven occurred at currents below the baseline limit as shown in Figure 10.6. The slope and intercept of a linear fit to the data argue for a physical mechanism that differs from the baseline quench mechanism. Note that the lap joints were cooled with liquid rather than supercritical helium. It is hypothesized that at high ramp rates, eddy current heating of the joints boiled away all or most liquid in the joint manifolds, resulting in poor heat transfer and consequently quenches at the joints.

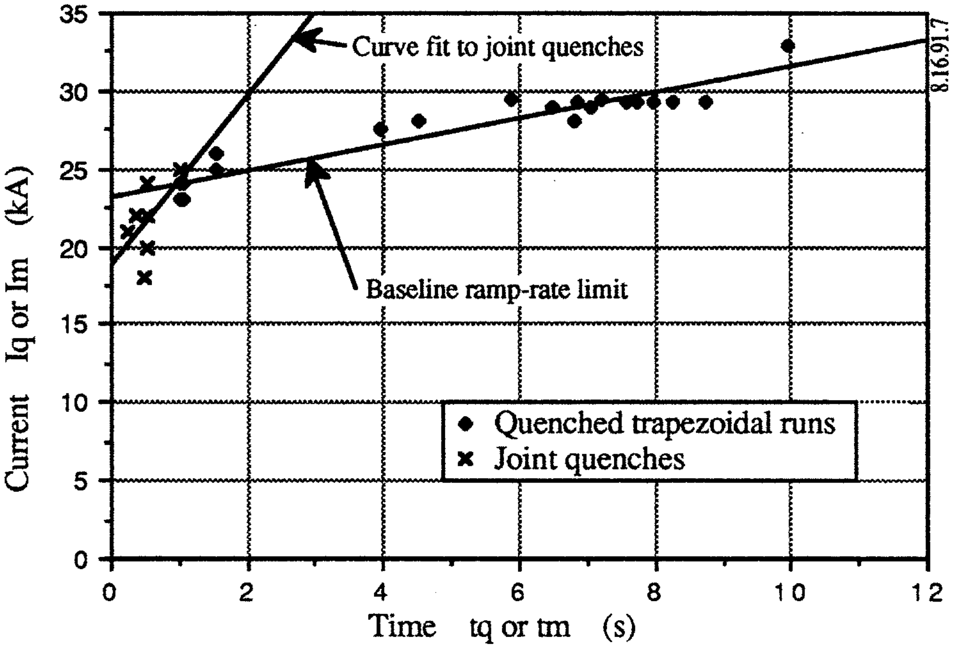


Figure 10.6- The interpancake lap joint quenches compared with the baseline ramp-rate limit. All lap joint quenches occurred at nominal ramp times of one second or less and five of the seven occurred at currents below the baseline limit.

10.3.2.2 Triangular-pulse runs

Of the 15 triangular-pulse runs, two showed normal-zone voltage rises as shown in Figure 10.7. The quenched runs exceeded the baseline ramp-rate limit by as much as 14%, and the non-quenched runs exceeded the baseline limit by as much as 27%.

Because the triangular pulses have no flattop currents, a quench-indicating voltage rise may have been undetectable due to the immediate, rapidly decreasing down-ramp current. As a check, Figure 10.8 plots the measured AC loss data of the non-quenched runs (all of which occurred at 0.5 second ramp times) as a function of the maximum current to see if the behavior of the measured losses could be accounted for by AC loss theory alone or if undetected normal zones created unpredictable increases in the measured losses due to joule heating. In this plot it is revealed that at currents between 20 and 25 kA, the measured AC losses begin to increase exponentially, deviating from the behavior predicted by the calculated losses and indicating joule heating has occurred. (Note that the apparently higher losses in pancake 5 are probably due to inaccurate mass flow measurements at the inlet of double pancake C.) A conclusion can be made that normal zones were initiated in the 0.5-second-ramp-time runs, but the quench detection system was not triggered due to the absence of a flattop current.

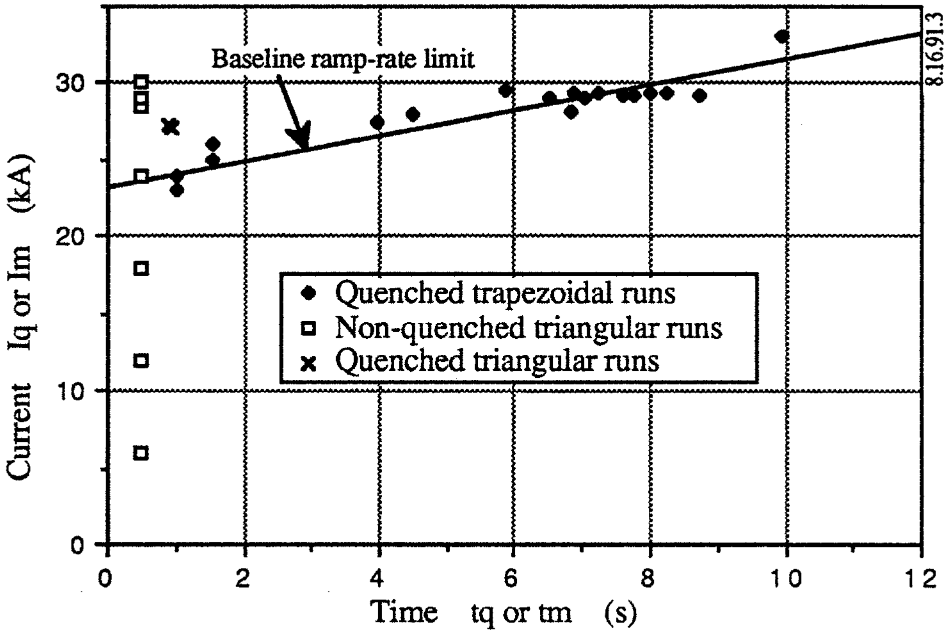


Figure 10.7 - The triangular-pulse runs compared to the baseline ramp-rate limit. The currents at 0.5 second ramp times appear to exceed the limit without quenches.

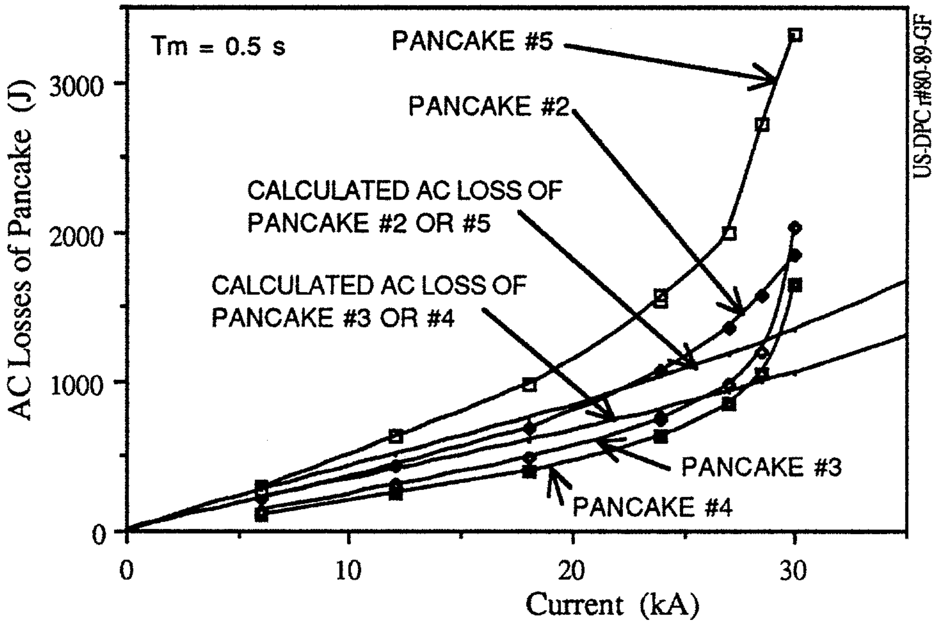


Figure 10.8 - The AC losses of individual pancakes from the non-quenched, triangular-pulse runs. At currents between 20 and 25 kA, the measured AC losses begin to increase exponentially, deviating from the behavior predicted by the calculated losses and indicating joule heating has occurred. Note that the apparently higher losses in pancake 5 are probably due to inaccurate mass flow measurements.

10.3.2.3 Round-edge trapezoidal-pulse runs

One of the eight round-edge trapezoidal-pulse runs quenched, as shown in Figure 10.9. The quenched run (no. 181) exceeded the baseline ramp-rate limit by 8.1%, and the non-quenched runs exceeded the baseline limit by as much as 12.1% (no. 180).

The significance of the round-edge trapezoids is that the ramp current I(t), given by Equation 10.2, creates a steadily decreasing ramp rate that eliminates the sharp transition to flattop (thought at the time of testing to initiate quench).

$$I(t) = (I_m / t_m)\, t + 0.283\, I_m \sin(\pi\, t / t_m) \qquad (10.2)$$

Two examples of the difference between round-edge and standard trapezoids are shown in Figure 10.10, which plots the current waveforms of runs 180 and 181 with the equivalent ramps of standard trapezoidal waveforms.

For the reader's reference, Figure 10.11 plots the ramp-rate variation of runs 180 and 181 during charging. It is evident that the ramp rates near the transition to flattop were significantly smaller than initial ramp rates.

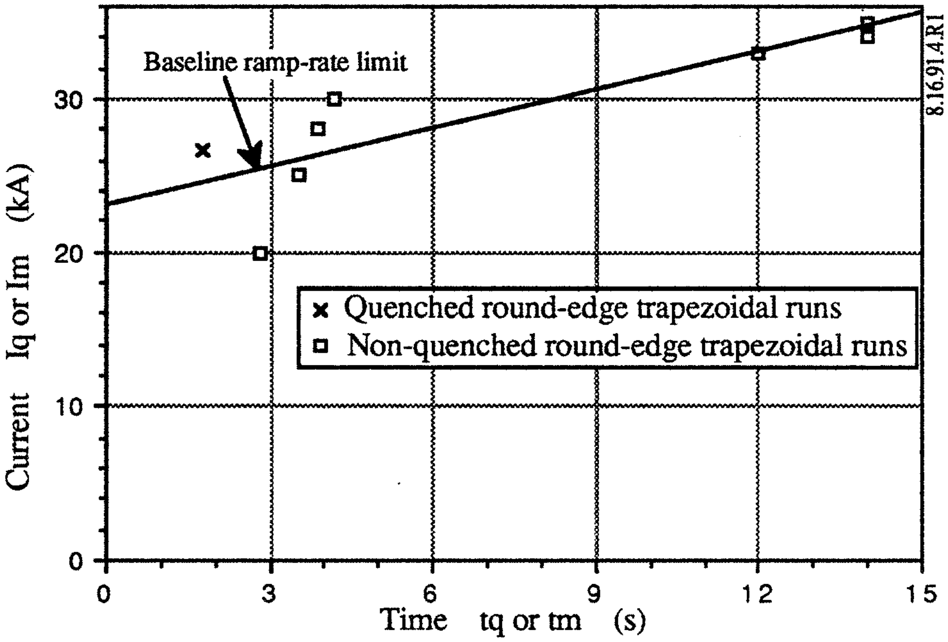


Figure 10.9 - The round-edge trapezoidal-pulse runs exceeded the baseline ramp-rate limit by 8.1% during the quenched run and by as much as 12.1% during the non-quenched runs

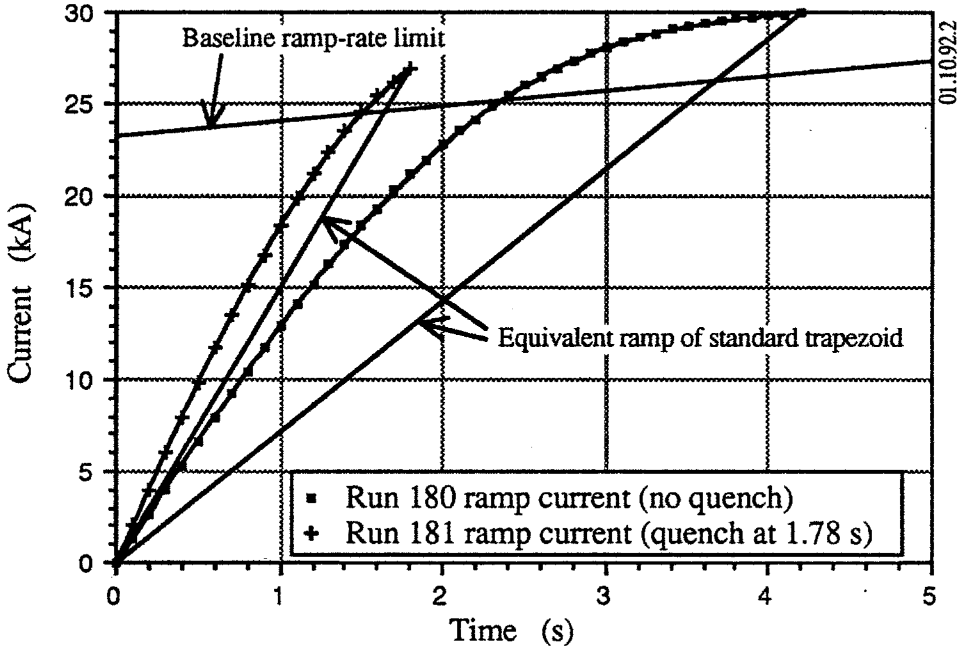


Figure 10.10 - The ramp currents of runs 180 and 181 illustrate the difference between the round-edge trapezoidal waveforms and the equivalent standard trapezoidal waveform.

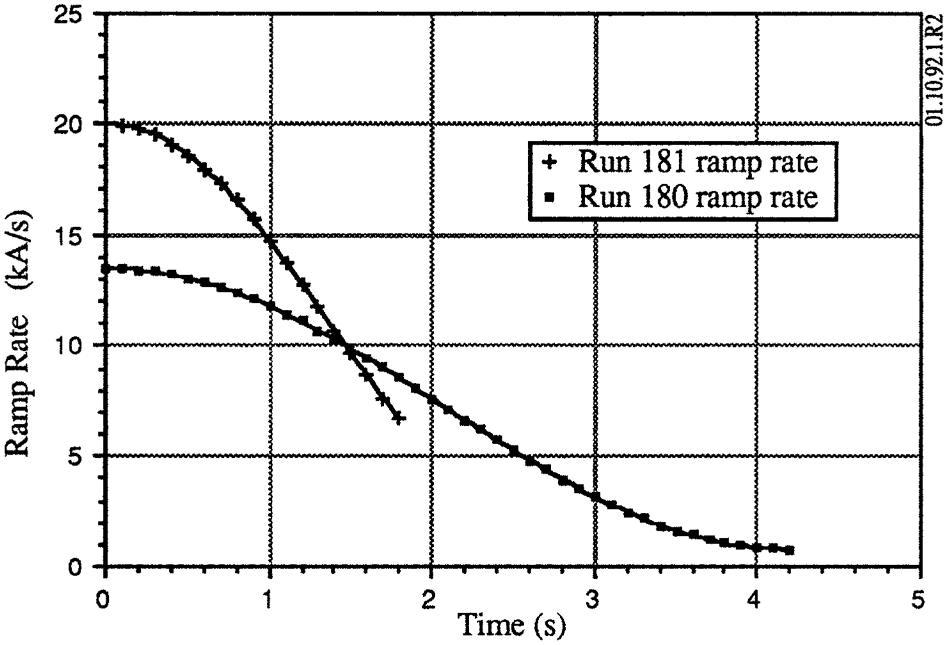


Figure 10.11 - Ramp-rate as a function of time for runs 181 and 180.

10.3.2.4 Rippled trapezoidal-pulse runs

Of the eight trapezoidal-pulse runs with AC current ripple, the baseline limit was exceeded by as much as 3.1% during the three quenched runs and by as much as 6.1% during the five non-quenched runs as shown in Figure 10.12. Contrary to expectations, these runs showed that the addition of a coupling-loss-inducing ripple to the charging waveform seems to slightly enhance the coil performance.

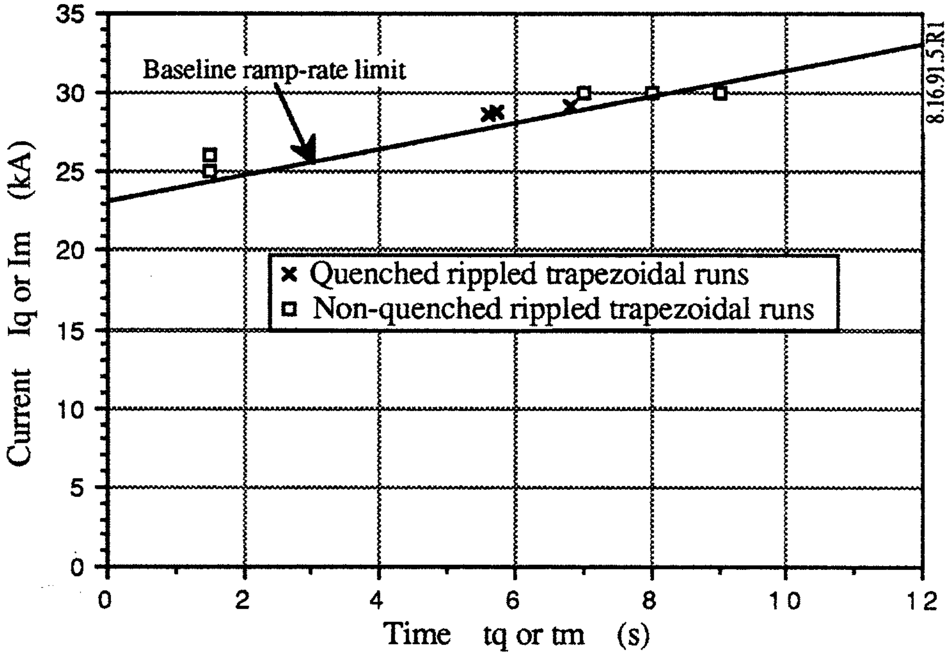


Figure 10.12 - Comparison of the baseline ramp-rate limit to data from trapezoidal waveforms that contained AC current ripple.

10.3.2.5 Two-step trapezoidal-pulse runs

Of the nineteen two-step trapezoidal-pulse runs, the baseline limit was exceeded by as much as 14.2% during the seven quenched runs and by as much as 16.6% during the twelve non-quenched runs as shown in Figure 10.13. It appeared that an intermediate flattop in the ramp allowed the baseline limit to be exceeded.

The intermediate flattops were of either one or three second nominal duration. The three second duration allowed cold inlet-helium to completely flow through the crossover turn and thereby reestablished the base temperature (nominally 4.5K) before initiating the second ramp. However, the duration of the flattop seemed to have no significant effect on the ramp stability as shown in Table 10.3. Four of the seven quenches had a three second intermediate flattop, indicating that reestablishment of the base temperature was insufficient to stabilize the coil.

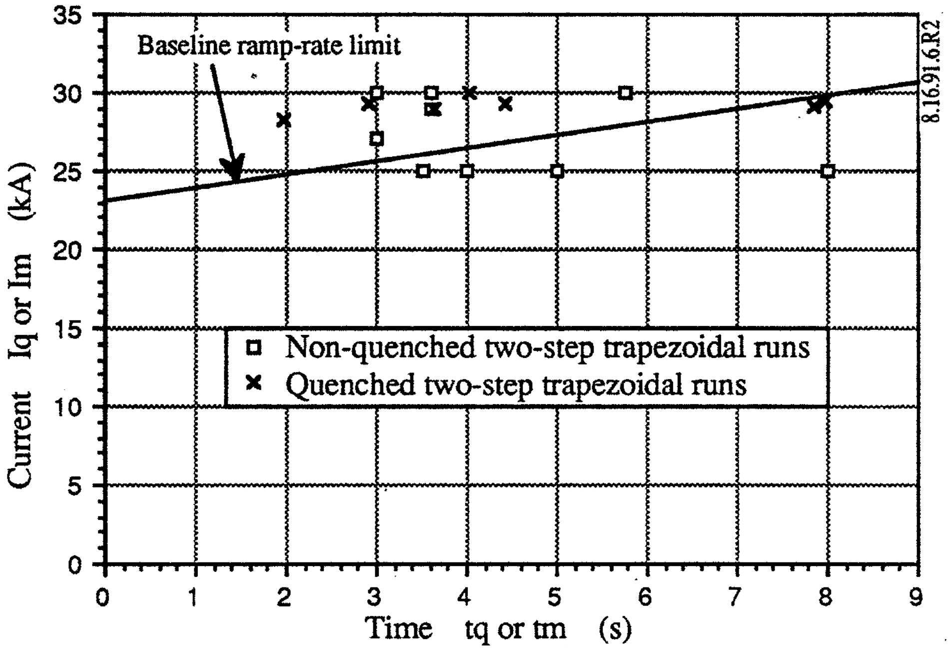


Figure 10.13- Comparison of the baseline ramp-rate limit to data from two-step trapezoidal-pulse runs.

Table 10.3 - Ramp data for the two-step trapezoidal-pulse runs.

run no.	quenched?	1st ramp time (s)	intermediate flattop current (kA)	intermediate flattop time (s)	2nd ramp time (s)	final current (kA)	total ramp time (s)
152	yes	0.75	22	0.98	0.32	30	2.05
153	yes	0.76	22	2.97	0.31	30	4.04
154	yes	0.77	22	2.96	0.77	30	4.5
217	yes	3.32	20	3	1.71	30	8.03
218	yes	3.69	22	3.01	1.34	30	8.04
220	yes	1.01	22	0.98	1.01	30	3
223	yes	1	22	1.01	1.57	29	3.58
150	no	1	22	1	1	27	3
151	no	1	22	1	1	30	3
155	no	2	22	3	0.75	30	5.75
195	no	4	20	3	1	25	8
196	no	1.6	20	3	0.4	25	5
197	no	0.8	20	3	0.2	25	4
198	no	0.4	20	3	0.1	25	3.5
219	no	1	22	1	1	27	3
221	no	1	22	1	1.6	30	3.6
222	no	1	22	1	1.6	30	3.6
224	no	1	22	1	1.6	29	3.6
225	no	1	22	1	1.6	29	3.6

10.3.3 Series-coil tests

The series-coil tests were limited to eighteen non-quenched and seven quenched runs (numbers 254 to 278). Of the seven quenches, six initiated in the middle turns and one initiated in the crossover turn of double pancake C. However, the middle turn quenches also showed normal zone voltages in the crossover turns, indicating that quench initiation occurred close to the crossover turn. Further analysis is required to quantify exact initiation points and times.

Because the middle-turn quench times could not be determined accurately, only the non-quenched, trapezoidal-pulse runs are plotted in comparison with the baseline ramp-rate limit as shown in Figure 10.14, which plots flattop current vs. ramp time, and 10.15, which plots flattop magnetic field vs. ramp time. Figure 10.14 shows that the non-quenched flattop currents fell below the currents predicted by the single-coil baseline limit. However, Figure 10.15 shows that the flattop magnetic fields fell approximately 50% above the fields predicted by the single-coil baseline limit. This implies that the ramp-rate limitation of by the US-DPC was more dependent on current than magnetic field.

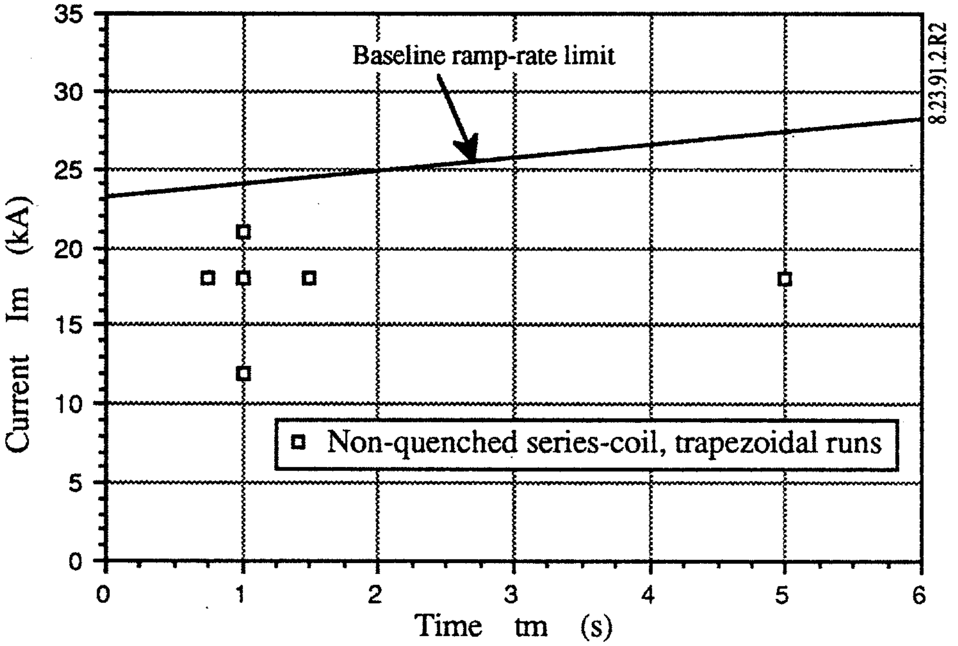


Figure 10.14 - The flattop currents of the non-quenched, series-coil, trapezoidal-pulse runs do not exceed the single-coil, baseline ramp-rate limit.

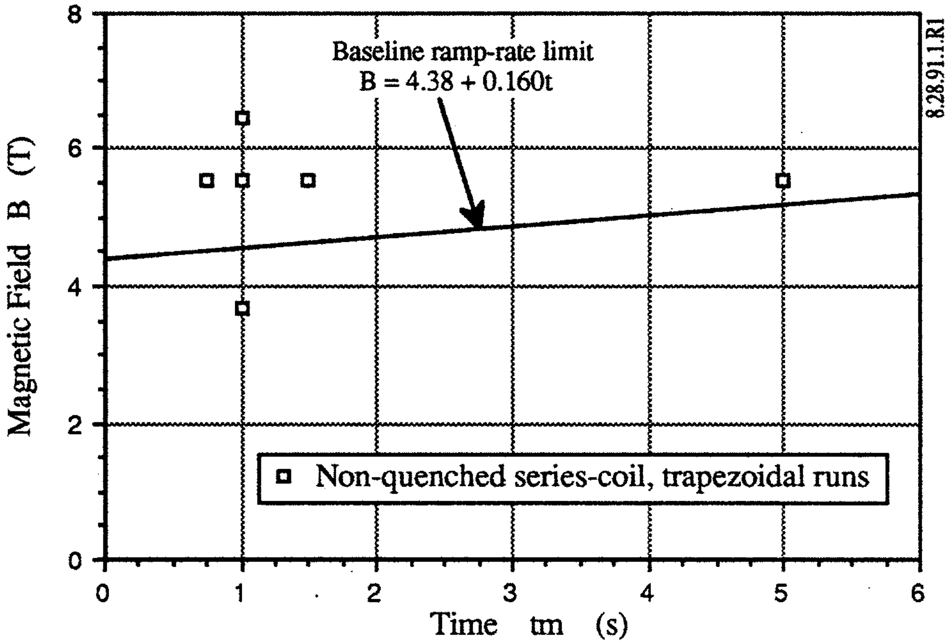


Figure 10.15 - Flattop magnetic fields of the non-quenched, series-coil, trapezoidal-pulse runs exceed the single-coil, baseline ramp-rate limit by as much as 50%.

10.4 Argument for limiting current

A threshold or "limiting" current may exist below which the US-DPC was unconditionally stable at any ramp rate in the single-coil mode. This current would be the intercept of the baseline limit, which equals approximately 23 kA. In support of the argument, Figure 10.16 compares the baseline limit with data from the two fastest-ramp, single-coil, trapezoidal-pulse runs (numbers 147, t_m = 300 ms and 148, t_m = 200 ms). Both runs were stable in the crossover and middle turns at these extraordinary ramp rates (di/dt ≈ 100 kA/s; dB/dt ≈ 20 T/s), although both quenched in the interpancake lap joints.

The term limiting current is interpreted here as the copper-stabilizer current at which Joule heating power equals helium cooling power. For transient disturbances during a ramp that cause a loss of superconductivity at currents below the limiting current, cooling would exceed heating and recovery should be theoretically possible. Limiting current takes the form[2]:

$$I_{lim} = \sqrt{\frac{A_{cu} p_w h (T_c - T_b)}{\rho}}$$

where A_{cu} is the stabilizer copper area, p_w is the wetted perimeter, h is the heat transfer coefficient, ρ is stabilizer resistivity, T_c is critical temperature and T_b is bath temperature.

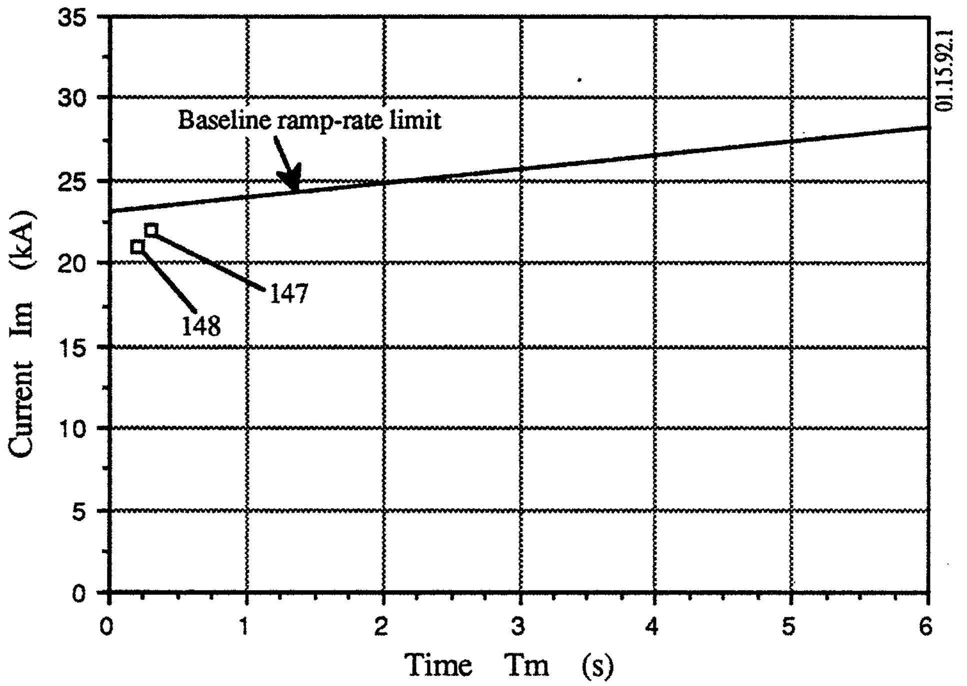


Figure 10.16 - The single-coil mode baseline ramp-rate limit has a 23 kA intercept. Runs 147 and 148 (ramp times of 300 and 200 ms respectively) were without quench in the crossover or middle turns and support the conjecture that below 23 kA the coil would be stable at any ramp rate.

References

1. T.Isono, et. al., "Power supply system for the Demo Poloidal Coils," MT-11, Vol.2, 1989, pp. 835 - 840.

2. L. Bottura et al, "Design criteria for stability in cable-in-conduit conductors," Cryogenics, Vol. 31, July 1991, pp. 510 - 515.

11. Lap joint resistance

The US-DPC consists of three double-pancakes joined together in series by two interpancake lap joints as described in section 5.3 and illustrated in Figure 5.4. The most important parameter of the lap joints is their electrical resistance, and in this chapter, the electrical resistance measurements are presented. Section 11.1 presents the geometry and fabrication steps of the lap joints, and section 11.2 presents the resistance measurements.

11.1 Joint description

The ribbon lap joints of the US-DPC have the geometry shown in Figure 11.1. The ribbons were made by undoing the last-stage cable transposition so that the 45-strand subcables could be placed side by side. During heat treatment of the superconductor, the copper stabilizers of the wires sintered to the 0.7-mm-wall CDA 102 copper tube into which they were placed. In addition to the copper-to-copper sinter bonds, the cable space of the ribbons was filled with 50/50 (Sn/Pb) soft solder after heat treatment. The mating surfaces of the conductor ribbons were tinned and soldered using 0.10 mm thick Sn/Pb/Cd (51/31/18) sheets between the ribbon surfaces. The connected or overlap length of the two lap joints is given in Table 11.1.

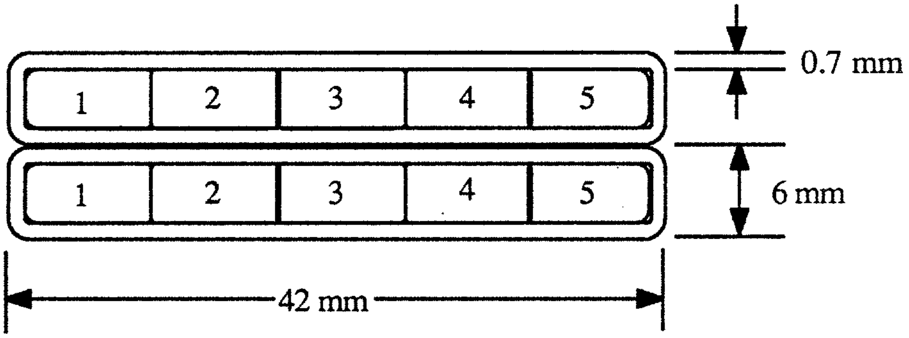


Figure 11.1 - Geometry of the US-DPC ribbon lap joints. The orientation of the ribbons in the coil was with the long side (42 mm) vertical. The ribbons were clamped between copper blocks not shown in the figure.

Table 11.1 - Length of ribbon lap joints in the US-DPC.

Joint	Length
A/B	941.1 ± 25 mm
B/C	871.2 ± 25 mm

11.2 Measured resistances

The resistance of the ribbon lap joints was measured during single-coil DC runs 23 - 25 and is presented as a function of current in Figures 11.2 and 11.3. The range of resistance was from 0.2 to 0.6 nΩ. Note that at 30 kA the field at the lap joints, which was approximately parallel to the 42 mm dimension, was 2.2 T in the single-coil mode.

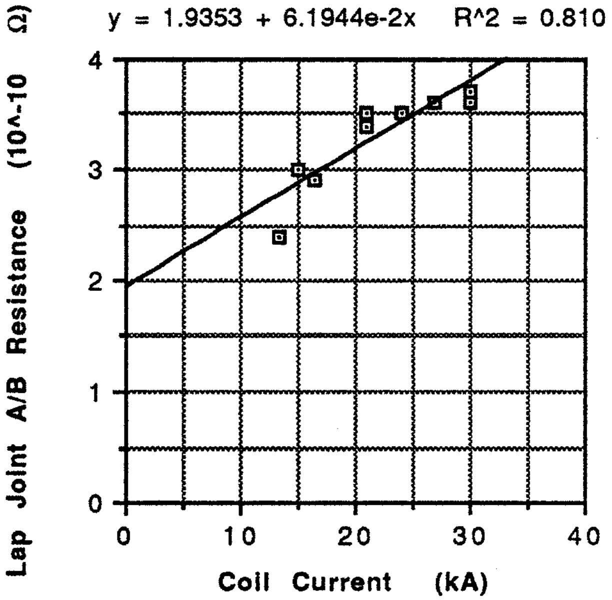


Figure 11.2 - Resistance of lap joint A/B as a function of coil current. Data were taken from single-coil runs 24 and 25.

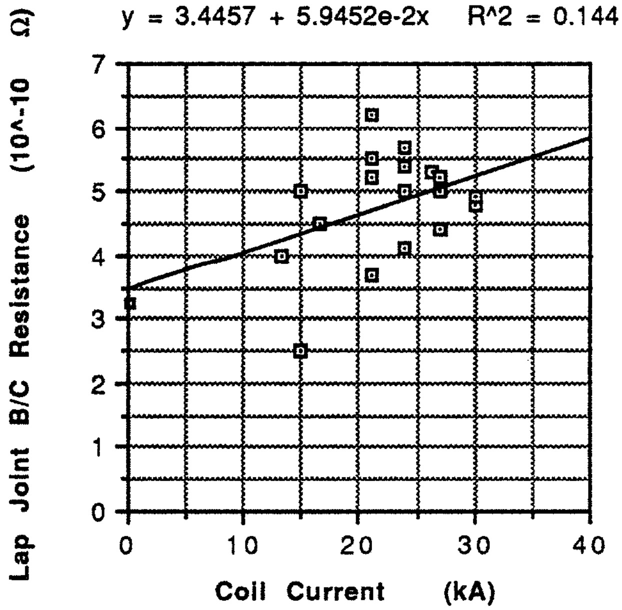


Figure 11.3 - Resistance of lap joint B/C as a function of coil current. Data were taken from single-coil runs 23 through 25.

12. Mechanical performance of the US-DPC

Mechanical behavior of the US-DPC was observed by displacement and strain measurements. Note that displacement in the axial direction could not be measured directly due to limited space and was inferred from strain measurements on bolts of the support structure.

12.1 Displacement measurements

Displacements in the radial direction at two points of the innermost turn of pancake 6 were measured by two extensometers, USDS01 and USDS02, as shown in Figure 12.1. These extensometers were mounted to poles fixed on the base plate of the coils. Each extensometer had a 10 mm movable rod of which the amount of movement was equal to the displacement. The extensometers were located so that the top of the rod touched the coil surface and the movable range was 5 mm. Since the coil base plate could not move, the measured displacements were absolute.

12.2 Sensors and locations

Strains of the coil support bolts that compress the whole coil stack were measured by strain gauges directly mounted on the centers of the bolt lengths. Sensor locations are shown in Figure 12.2. The mechanical behavior of the stack was monitored by strain measurements of the support bolts during DC tests.

12.3 Displacement measurements during DC tests

In the figures of this section, positive values of displacement show that the coil contracts, and negative values show that the coil expands. The average value (which eliminates coil movement resulting from stack misalignment) should be used when mechanical behavior of the coil is discussed.

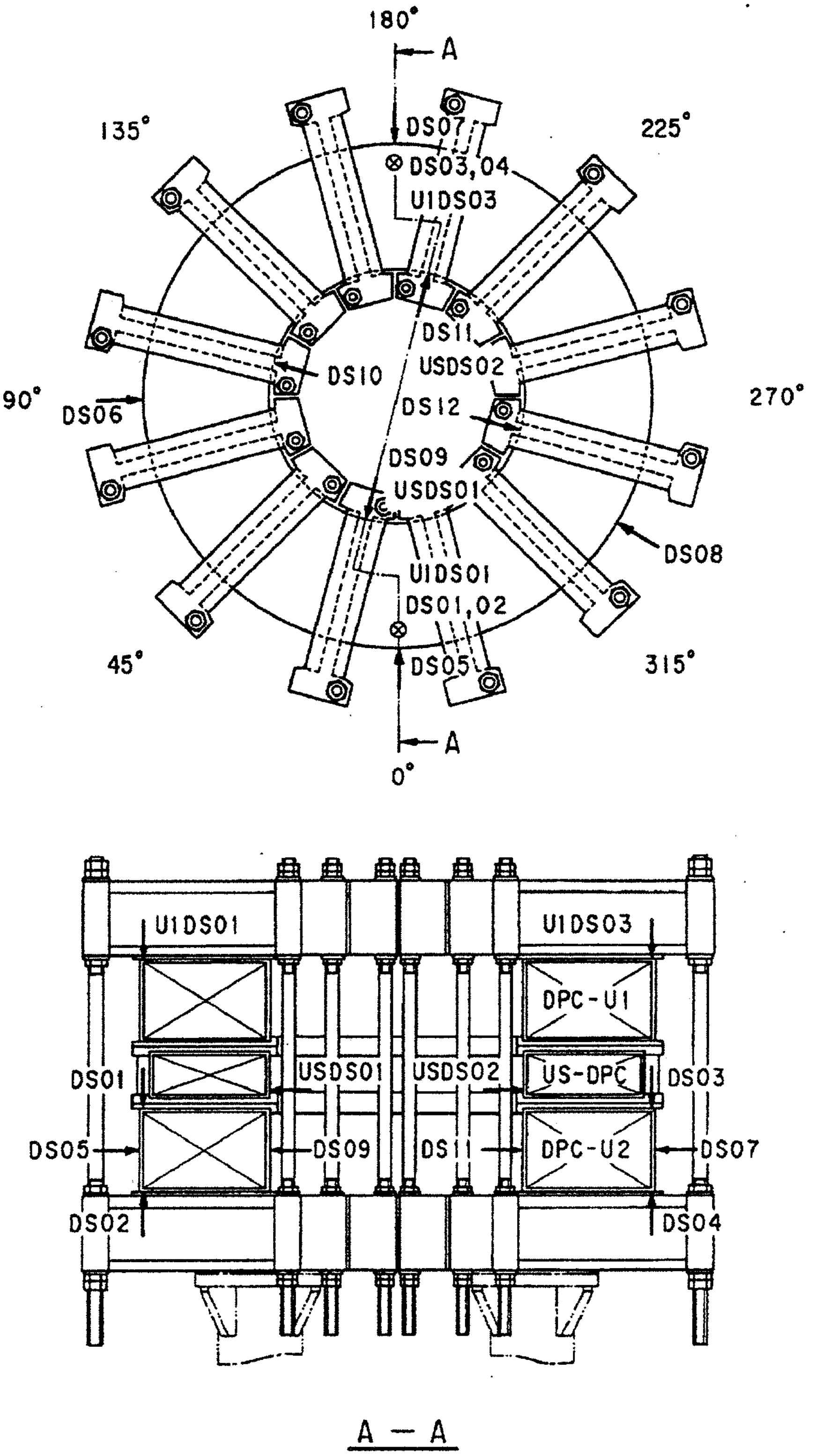


Figure 12.1 - The location of the extensometers, USDS01 and USDS02 are shown on the top view and side view of the coil stack (U1 + US-DPC + U2). The radial displacements are measured at the innermost turn of pancake 6 of the US-DPC.

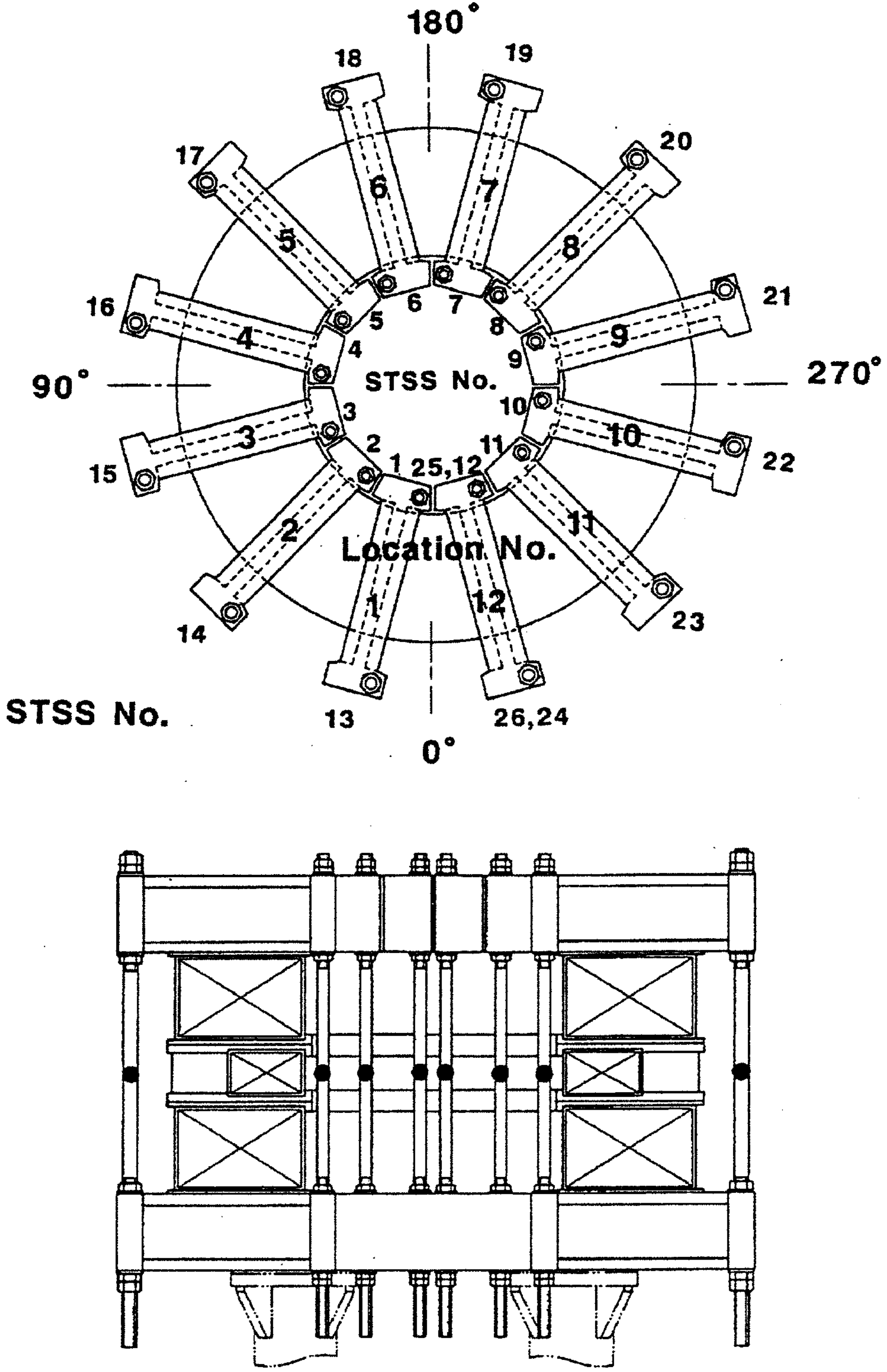


Figure 12.2 - The location of the strain gauges are shown on the top view and side view of the coil stack (U1 + US-DPC + U2). The strain gauges are mounted on the bolts which precompress the coil stack before cooling down.

12.3.1 Single-coil tests

12.3.1.1 XT recorder charts

Figures 12.3 through 12.8 show XT charts of current and displacements (USDS01 and USDS02) of run numbers 18, 20 and 23. The discontinuous points of displacement match with balance voltage spikes and are shown by arrows in these figures. It seems that the whole coil moved as the magnetic force was increased because a positive displacement was measured in USDS01. The XT recorder charts given here are summarized in Table 12.1.

Table 12.1 - Summary of XT recorder charts.

Figure number	Chart number	Shot	From	To	Number of Spikes	
					DS01	DS02
12.3	XT	#18	18 kA	21 kA	2	2
12.4	XT	#20	18 kA	21 kA	0	0
12.5	XT	#20	24 kA	27 kA	0	0
12.6	XT	#20	27 kA	27 kA	1	0
			27 kA	30 kA	1	1
12.7	XT	#23	24 kA	27 kA	0	0
12.8	XT	#23	27 kA	30 kA	0	0

Two discontinuous points with balance voltage spikes in both USDS01 and USDS02 are observed in the first charge (run number 18) between 18 kA and 21 kA as shown in Figure 12.3. However, in the second charge (run number 20) displacements smoothly increase with increase of current between 18 kA and 21 kA as shown in Figure 12.4. In run number 20, the displacement record is serrated and a few discontinuous points with balance voltage spikes are observed over 24 kA which is the virgin region for the coil as shown in Figures 12.5 and 12.6. The smooth displacement records over 24 kA in the second charge (run number 23) are obtained as shown in Figures 12.7 and 12.8.

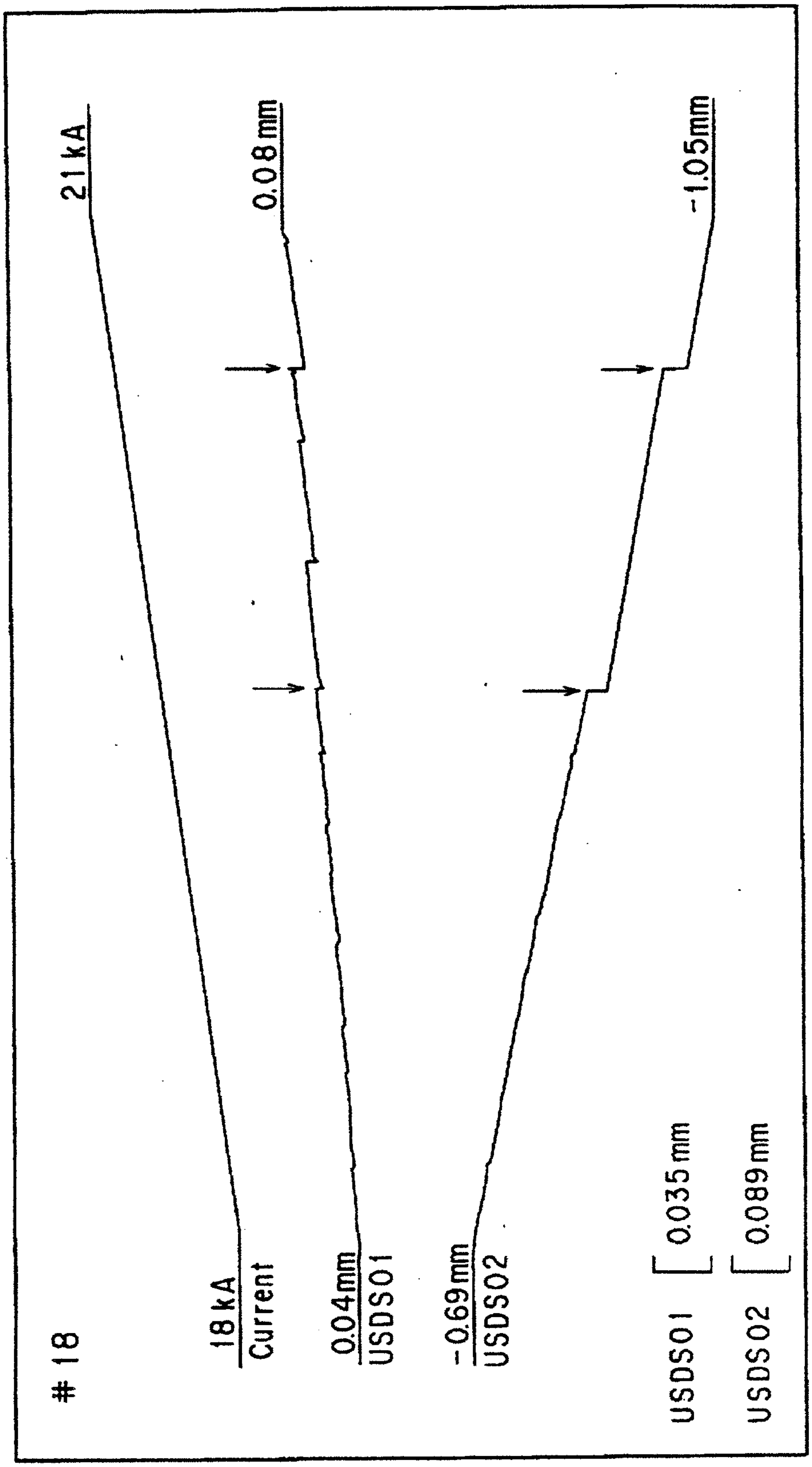


Figure 12.3 - The XT chart recording of the current and extensometers, USDS01 and USDS02, for run number 18 from 18 kA to 21 kA.

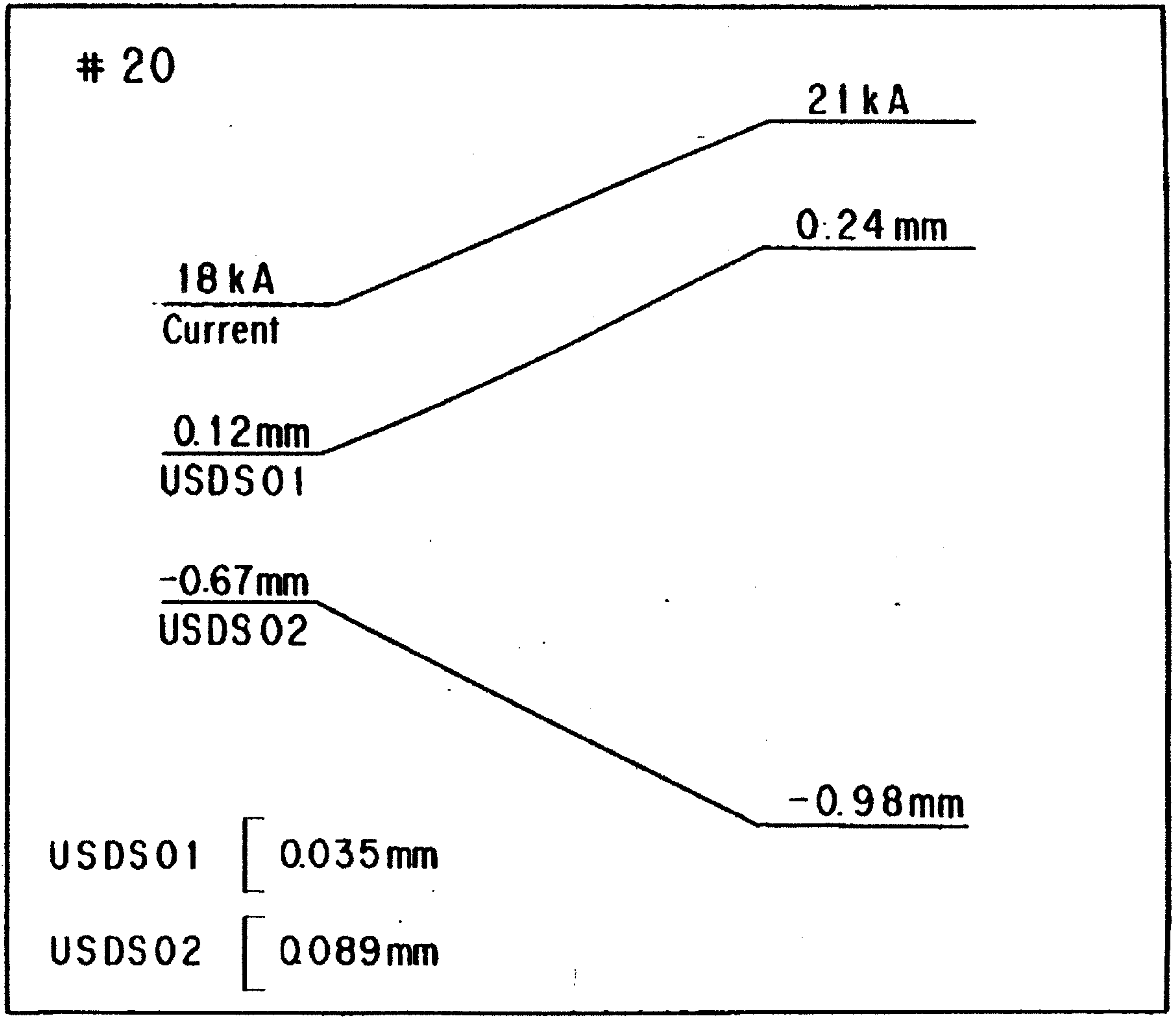


Figure 12.4 - The XT chart recording of the current and extensometers, USDS01 and USDS02, for run number 20 from 18 kA to 21 kA.

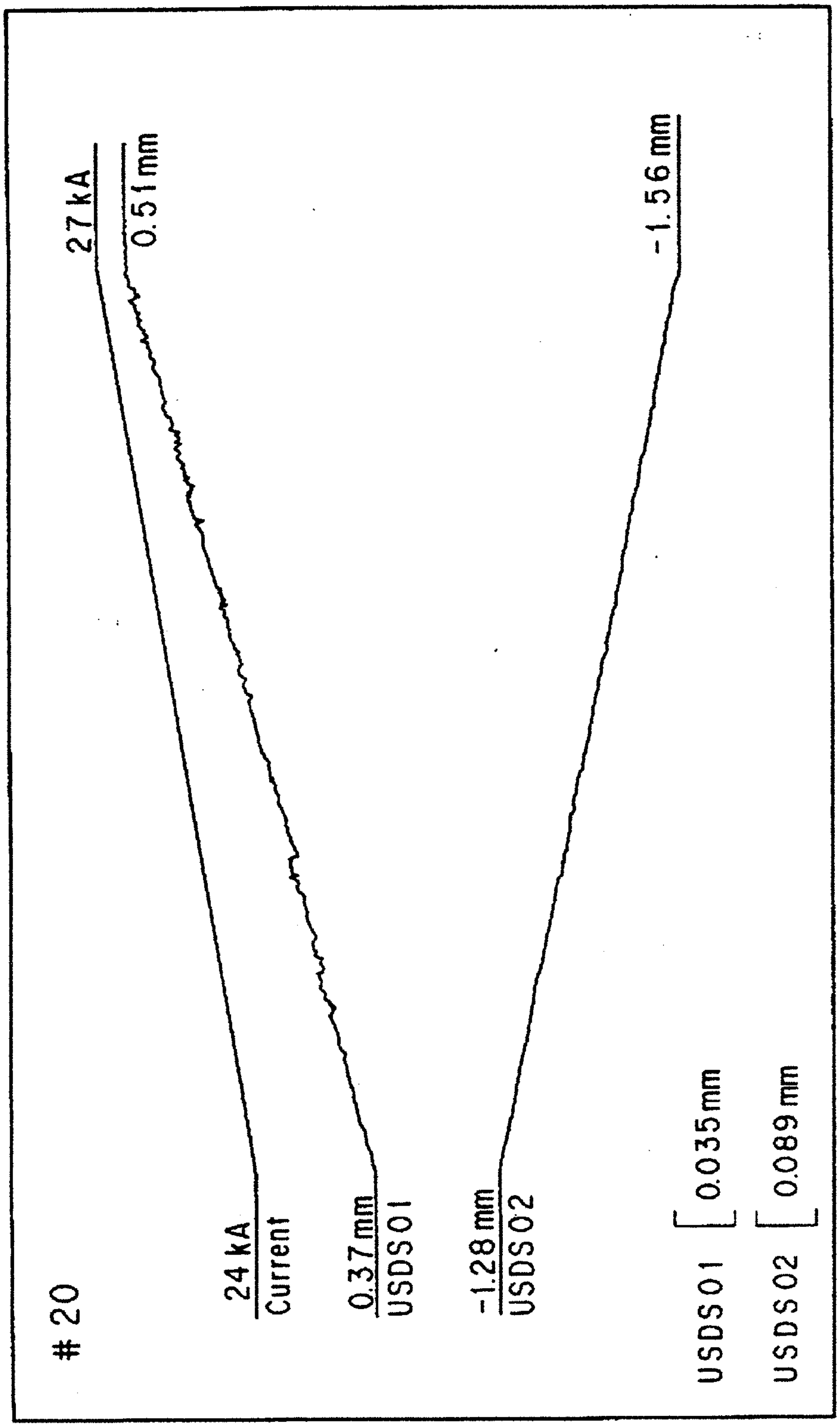


Figure 12.5 - The XT chart recording of the current and extensometers, USDS01 and USDS02, for run number 20 from 24 kA to 27 kA.

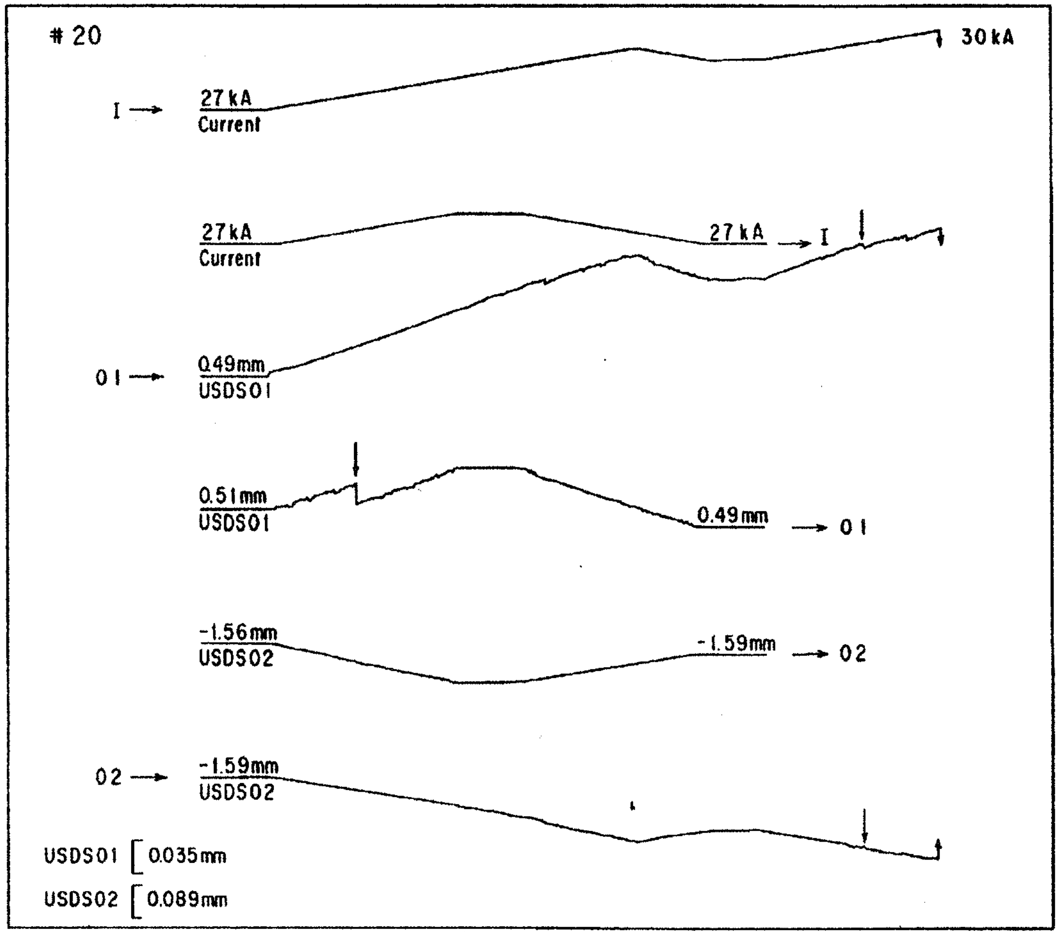


Figure 12.6 - The XT chart recording of the current and extensometers, USDS01 and USDS02, for run number 20 from 27 kA to 30 kA and from 27 kA to 27 kA.

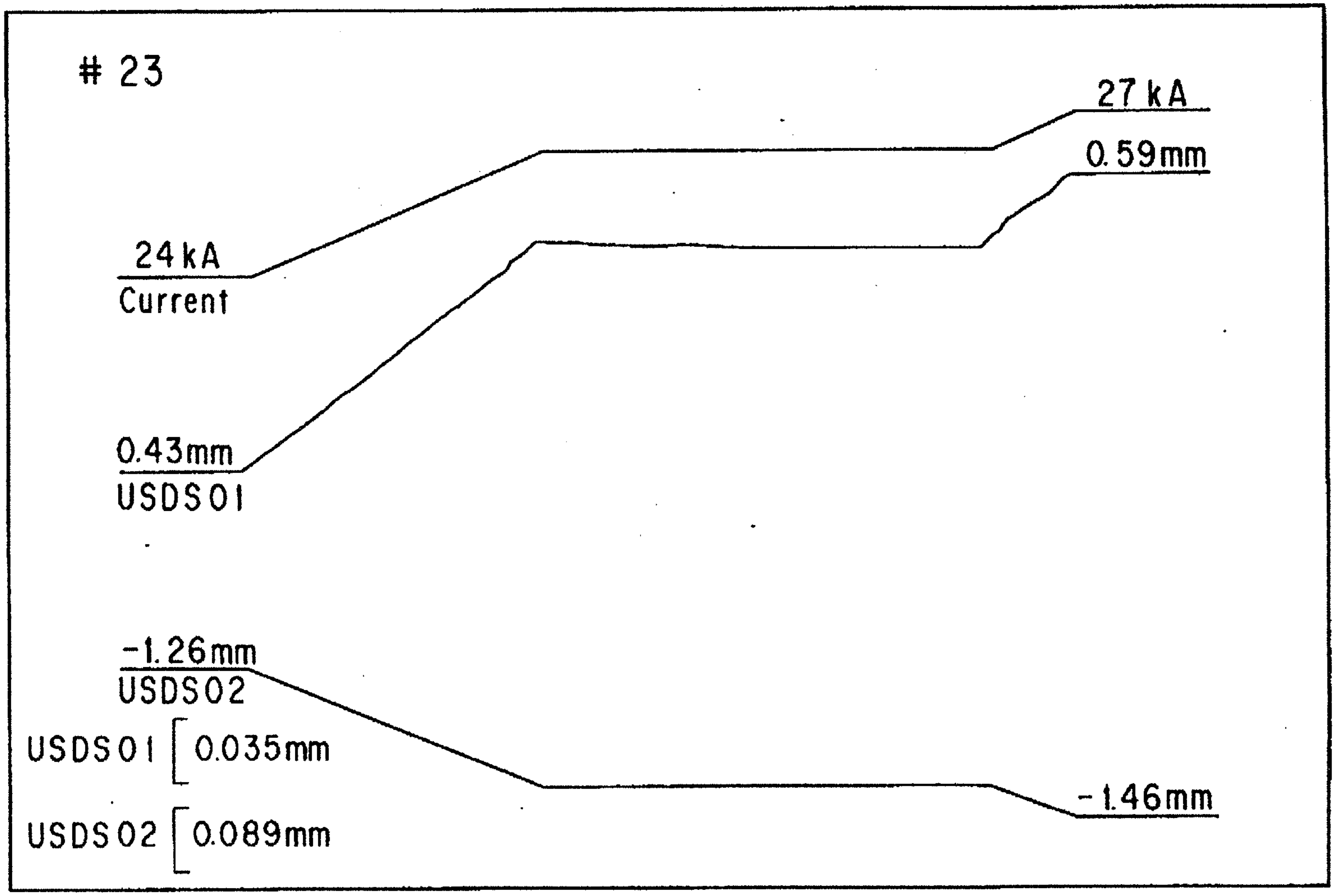


Figure 12.7 - The XT chart recording of the current and extensometers, USDS01 and USDS02, for run number 23 from 24 kA to 27 kA.

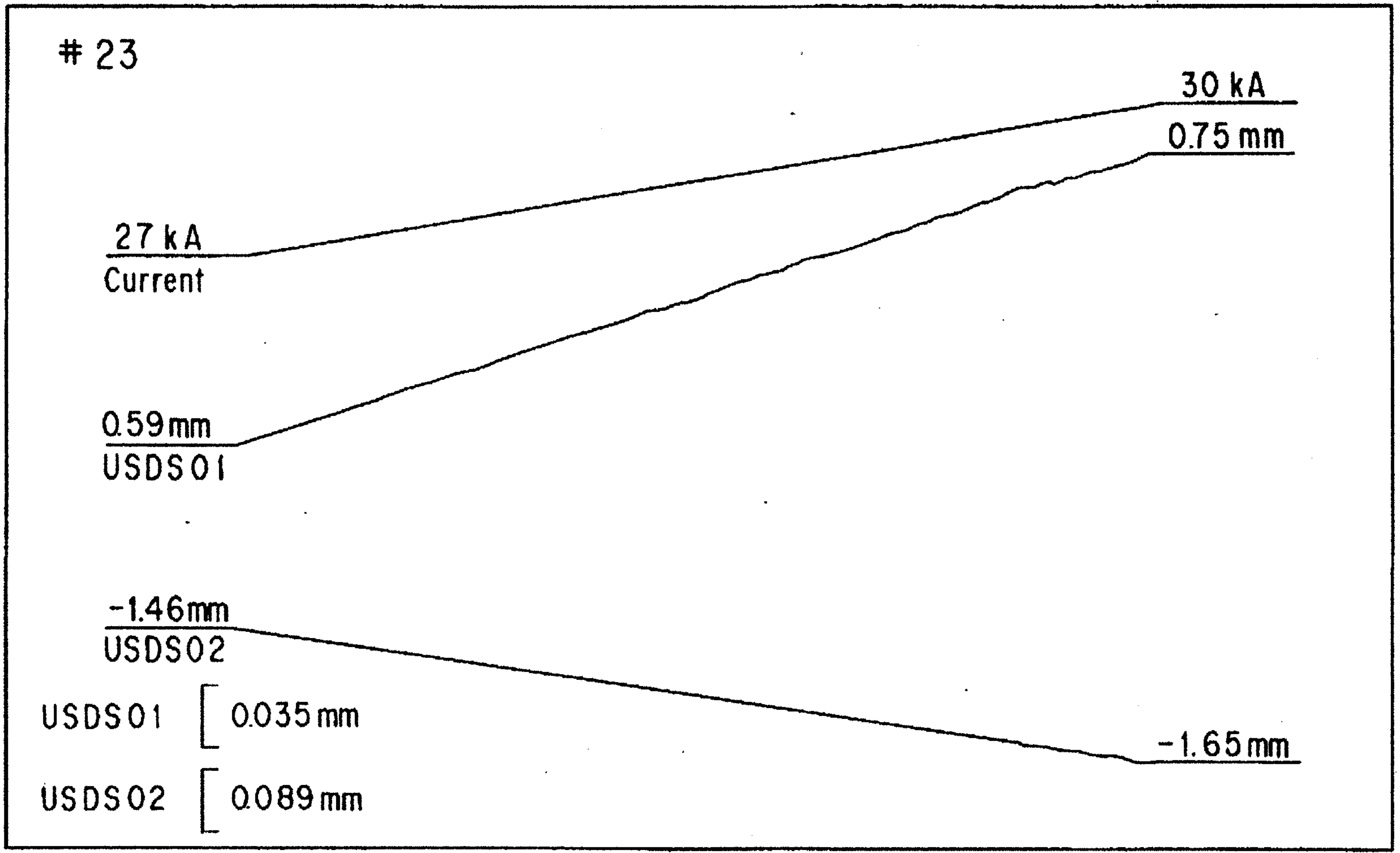


Figure 12.8 - The XT chart recording of the current and extensometers, USDS01 and USDS02, for run number 23 from 27 kA to 30 kA.

12.3.1.2 XY recorder charts

XY charts of run numbers 24 and 32 in which currents are charged up to 30 kA are shown in Figures 12.9 and 12.10, respectively. A small hysteresis effect is observed in both USDS01 and USDS02. Figure 12.11 shows a comparison between run numbers 24 and 32. In USDS01, the displacement of run number 32 is about 0.2 mm larger than that of run number 24. In USDS02, the displacements are about the same.

12.3.1.3 Relation between displacement and current squared

As mentioned above, the average value in which the coil movement is eliminated should be used when the mechanical behavior of the coil is discussed. The displacements which are plotted as a function of current squared are shown in Figures 12.12 and 12.13. A residual displacement after discharge is observed in run number 18 (the first charge) as shown in Figure 12.12. The data of run numbers 20, 23, 24, 25 are plotted in Figure 12.13. The residual displacements disappear and good reproducibility is obtained after run number 18. Usually, the average displacements are in proportion to current squared. But in the case of US-DPC, the average displacements of USDS01 and USDS02 are not in proportion to current squared in wide range from 0 kA^2 to 900 kA^2. Up to 300 kA^2, the displacements are in proportion to current squared, but over 300 kA^2, the displacements saturate. The maximum average value at 30 kA is about 0.45 mm (run numbers 23 through 25). In addition, it has a scatter between 0.35 mm (run numbers 33 through 38) and 0.53 mm (run numbers 66 through 69).

12.3.2 Series-coil tests (U1+U2+US)

12.3.2.1 XY recorder charts

The XY chart of run number 58 (see Fig. 8.1) is shown in Figure 12.14. A decrease of displacement during the long holds is observed in this figure. The configuration of measured curves is similar to that of the single-coil tests.

12.3.2.2 Relation between displacement and current squared

The displacement plotted as a function of current squared is shown in Figure 12.15. The configuration of the measured curves is similar to that of the single-coil tests. In addition, measured values are slightly larger than those of the single-coil tests. Up to 200 kA^2, displacements are proportional to current squared, but over 200 kA^2, displacements saturate. The maximum average value at 30 kA is about 0.6 mm.

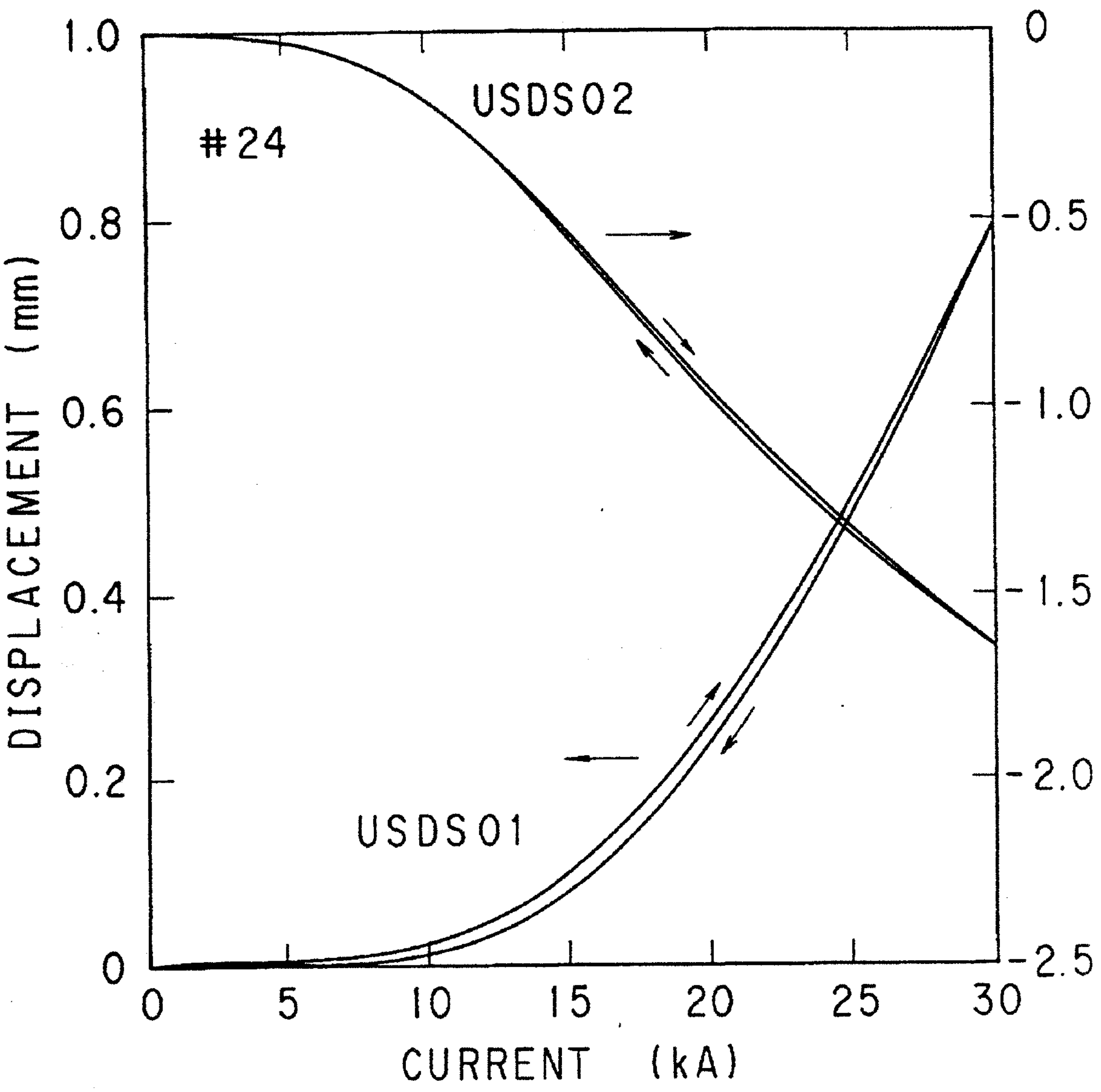


Figure 12.9 - The XY chart recording of the current and extensometers, USDS01 and USDS02, for run number 24 reveal a small hysteresis effect in the displacement as the US-DPC is charged from 0 to 30 to 0 kA.

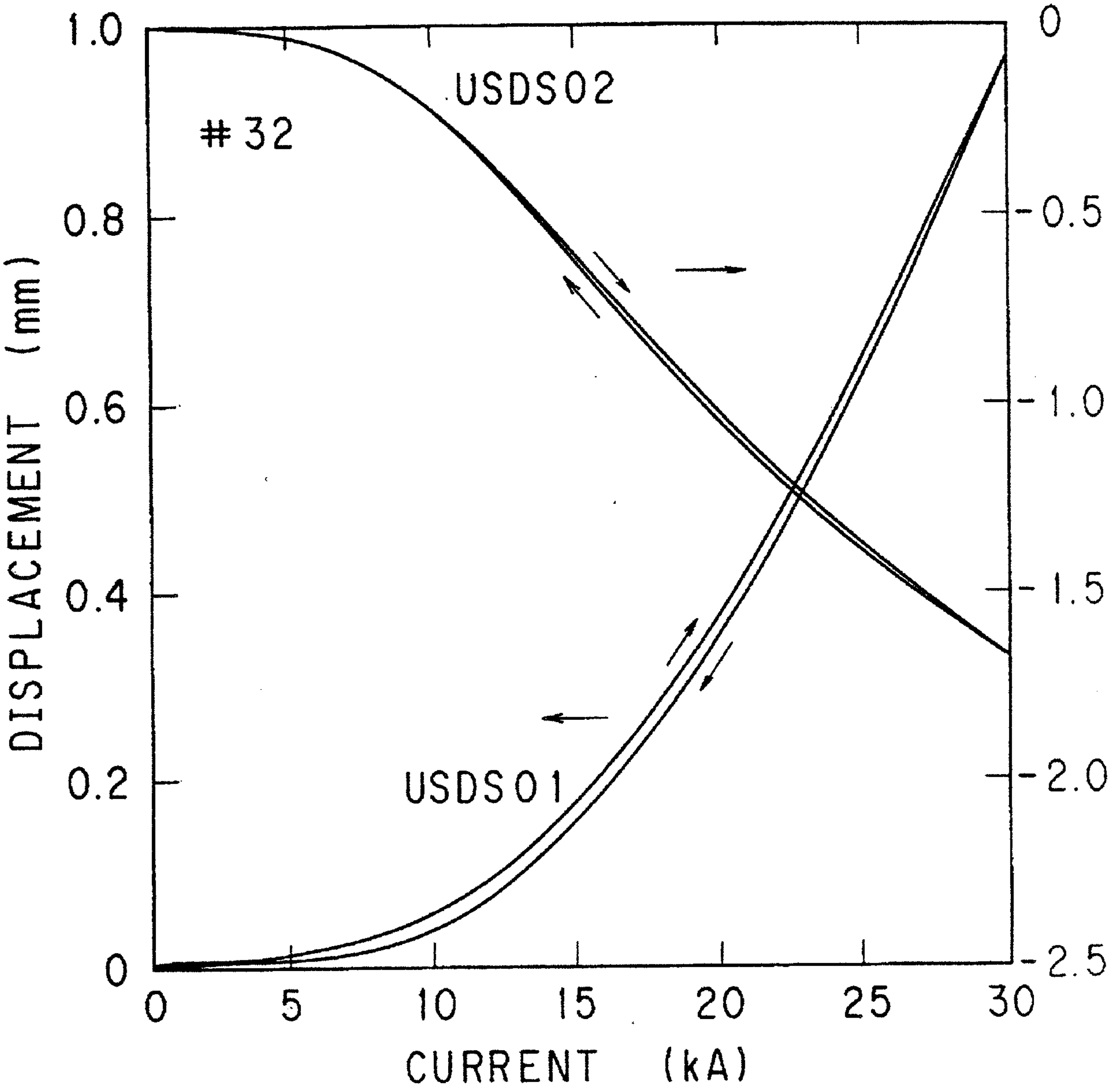


Figure 12.10 - The XY chart recording of the current and extensometers, USDS01 and USDS02, for run number 32 reveal a small hysteresis effect in the displacement as the US-DPC is charged from 0 to 30 to 0 kA.

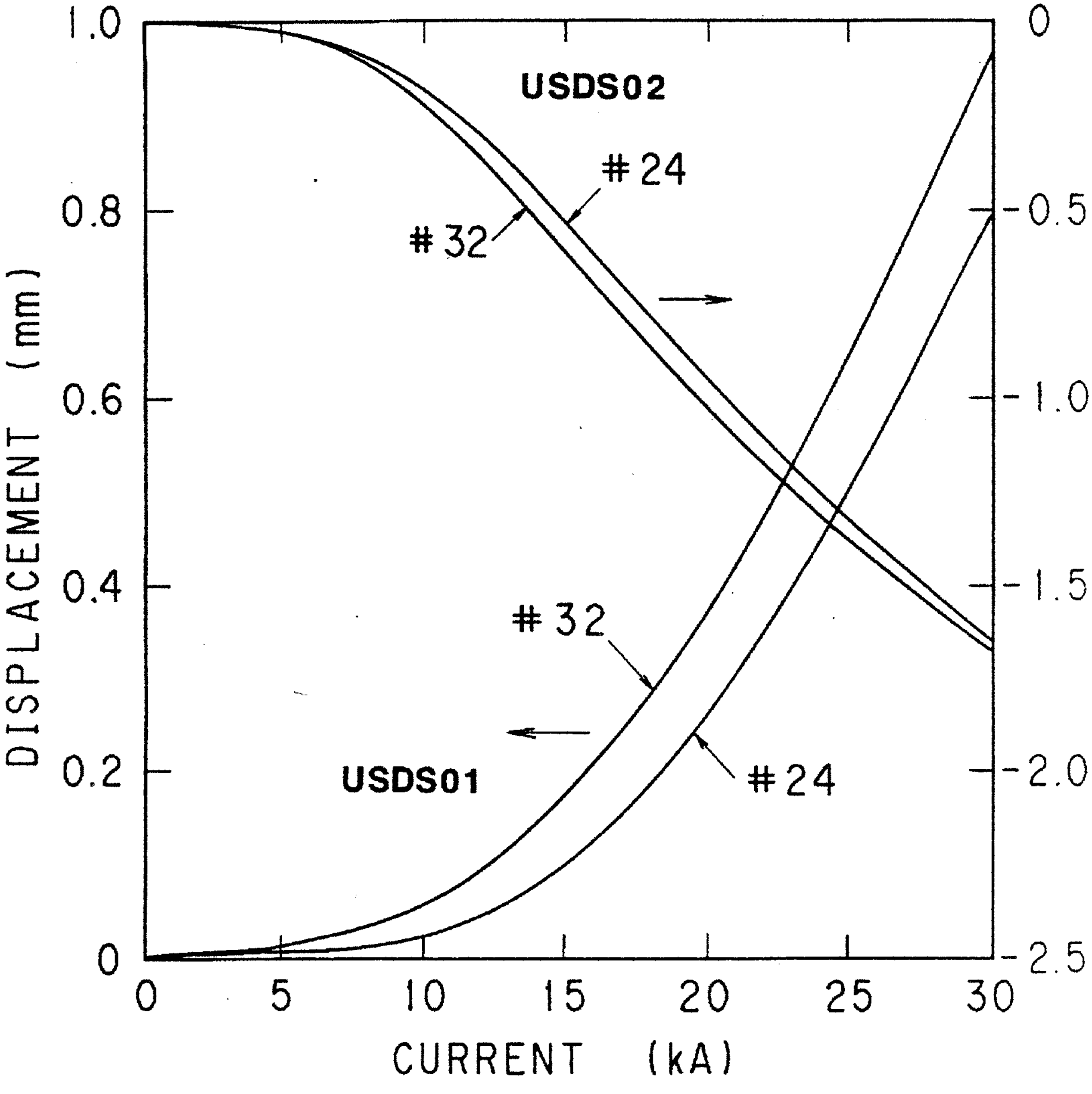


Figure 12.11 - The XY chart recording of the current and extensometers, USDS01 and USDS02, compare the differences in the hysteresis effect of run numbers 24 and 32.

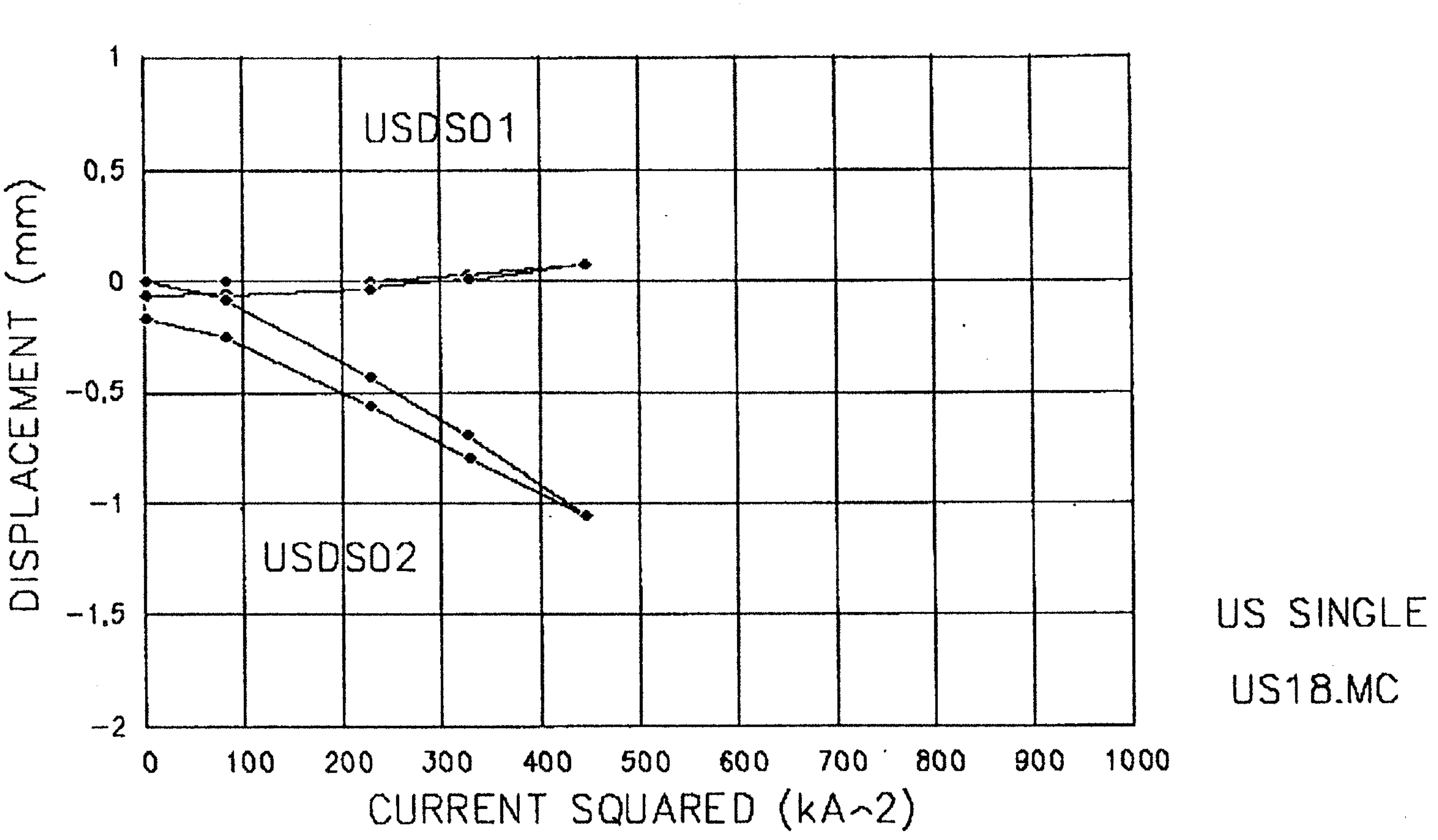


Figure 12.12 - Run number 18 shows a residual displacement in the radial direction of the US-DPC after discharge.

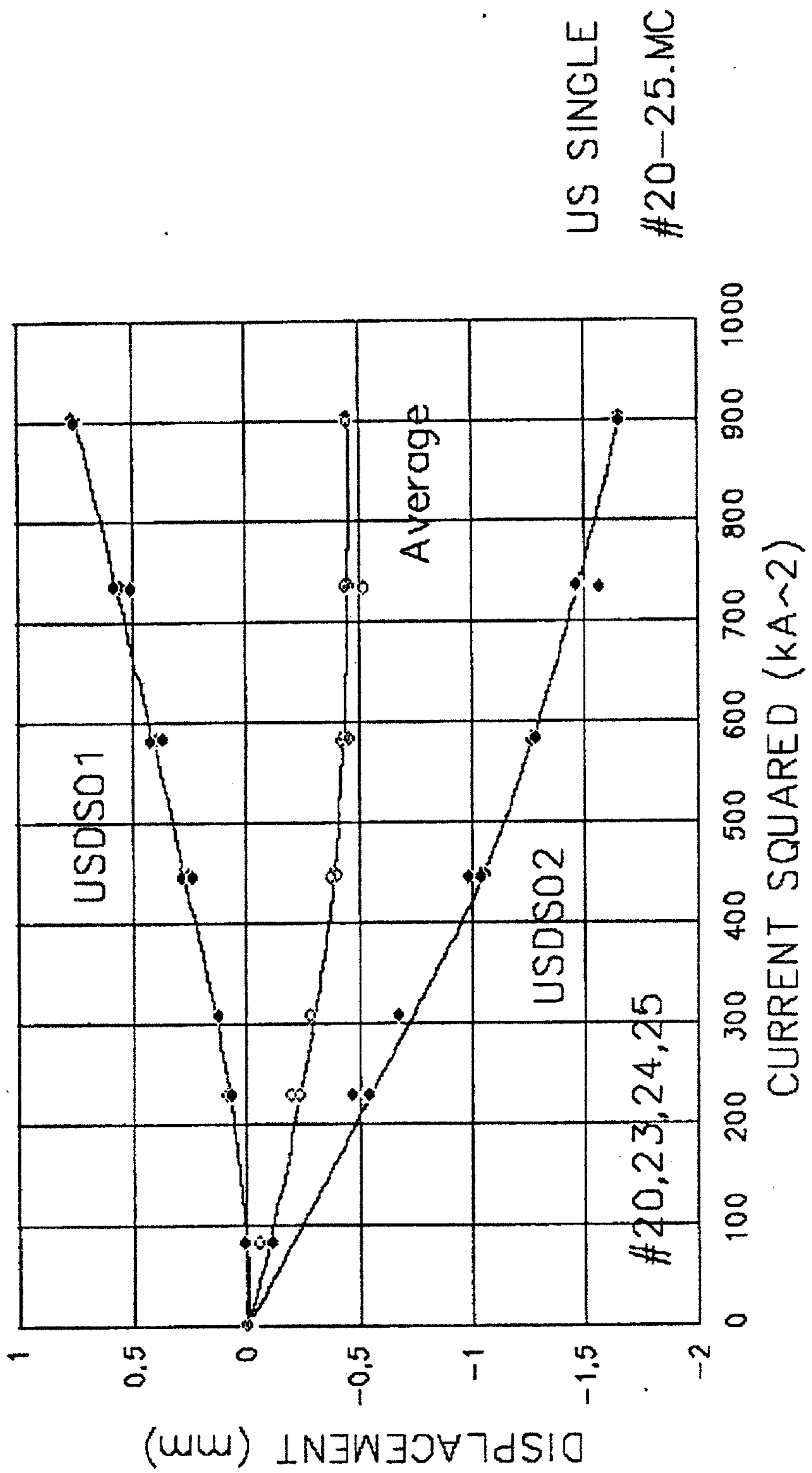


Figure 12.13 - The plots of radial displacement versus current squared for run numbers 20, 23, 24, and 25 (single-coil tests) show that after run number 18, the residual displacements after discharge disappear and good reproducibility is obtained.

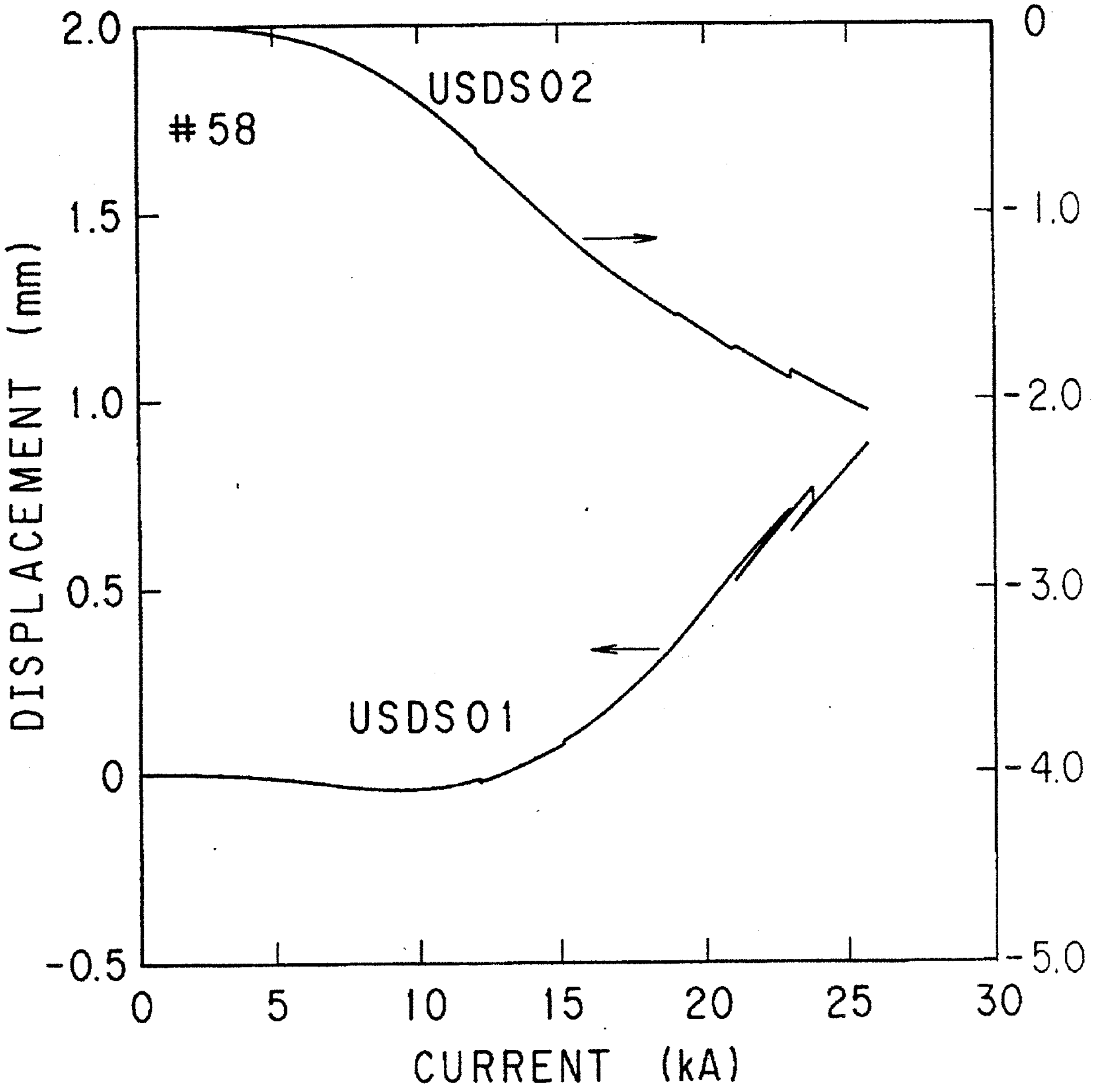


Figure 12.14 - The plots of radial displacement versus current for run number 58 show a reaction similar to the single-coil test measurements.

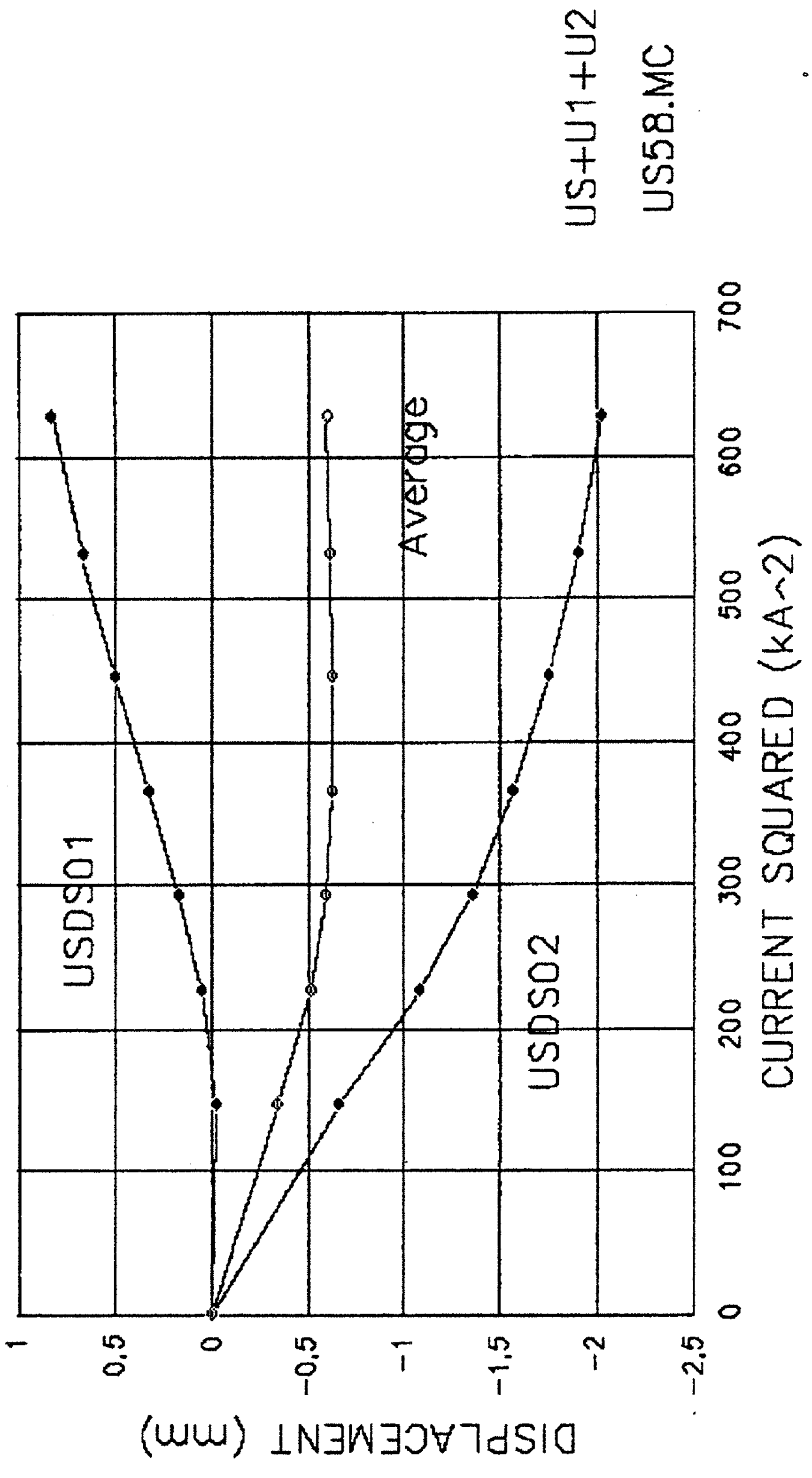


Figure 12.15 - The plots of radial displacement versus current squared for run number 58 (series-coil test) show a reaction similar to, but slightly larger than, the single-coil test measurements.

12.4. Displacement measurements during AC tests

12.4.1 Single-coil tests

12.4.1.1 XT recorder charts

Figures 12.16 through 12.19 show XT charts of current and displacements (USDS01 and USDS02) of run numbers 124, 175, 180, and 243. The figures show the displacement curves corresponding to the various current patterns.

12.4.1.2 XY recorder charts

The XY charts of run numbers 155 and 243, where the current was charged to 30 kA, are shown in Figures 12.20 and 12.21, respectively. A small hysteresis effect is observed in both USDS01 and USDS02 similar to the DC charge tests. Figure 12.22 shows a comparison between run numbers 155 and 243. In USDS01, the displacement of run number 155 is about 0.2 mm larger than that of run number 243, and in USDS02, the displacement of run number 155 is about 0.05 mm larger than that of run number 243.

12.4.1.3 Relation between displacement and current squared

The displacements plotted as a function of current squared are shown in Figure 12.23. The data obtained from the XT charts between run numbers 84 and 251 are used in this figure. The curves obtained from the AC tests agree well with those from the DC tests, if a measurement error is taken into account (compare Figures 12.13 and 12.23). The maximum average value at 30 kA was about 0.5 mm.

12.4.2 Series-coil tests (U1+U2+US)

12.4.2.1 XY recorder charts

The XY chart of run number 270 is shown in Figure 12.24, which shows the displacement curves corresponding to the current pattern.

12.4.2.2 Relation between displacement and current squared

The displacement plotted as a function of current squared is shown in Figure 12.25. The data obtained from the XT charts between run number 258 and 278 is used in this figure. The curves obtained from the series AC tests agree with the data from the DC tests, (compare Figures 12.15 and 12.25). As in the single-coil tests, the maximum average value at 30 kA was about 0.5 mm.

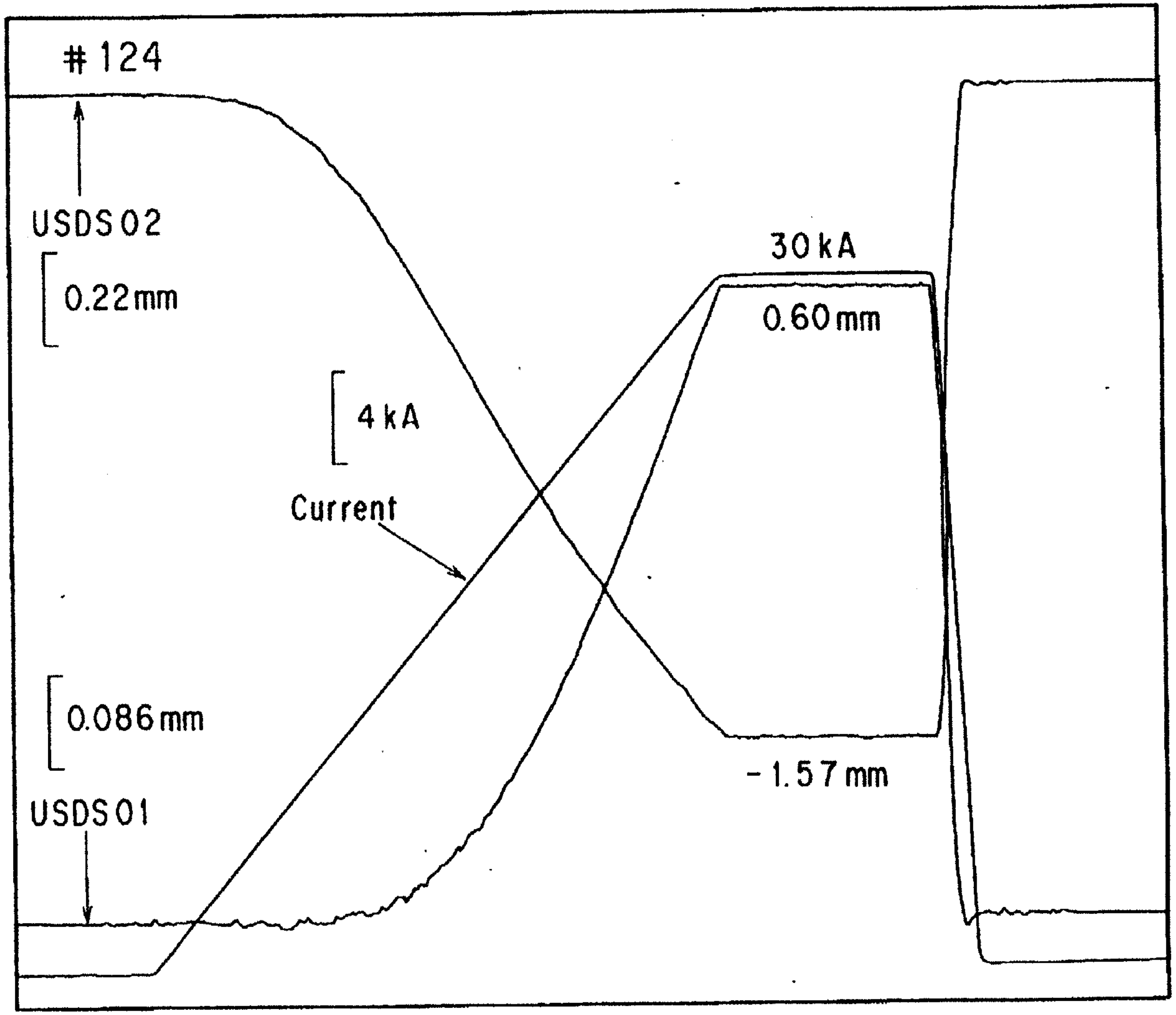


Figure 12.16 - The plots of radial displacement and current are shown for run number 124.

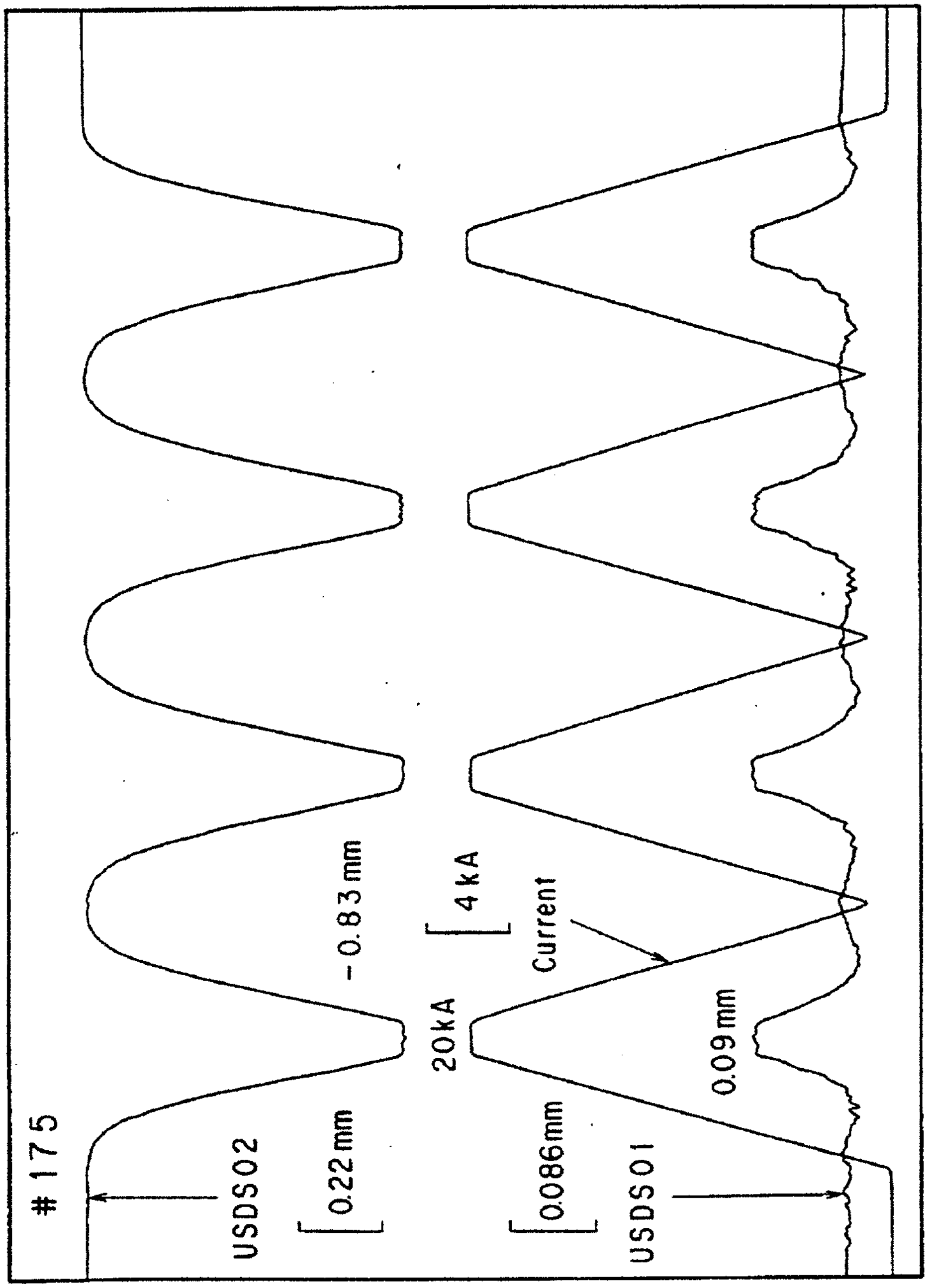


Figure 12.17 - The plots of radial displacement and current are shown for run number 175.

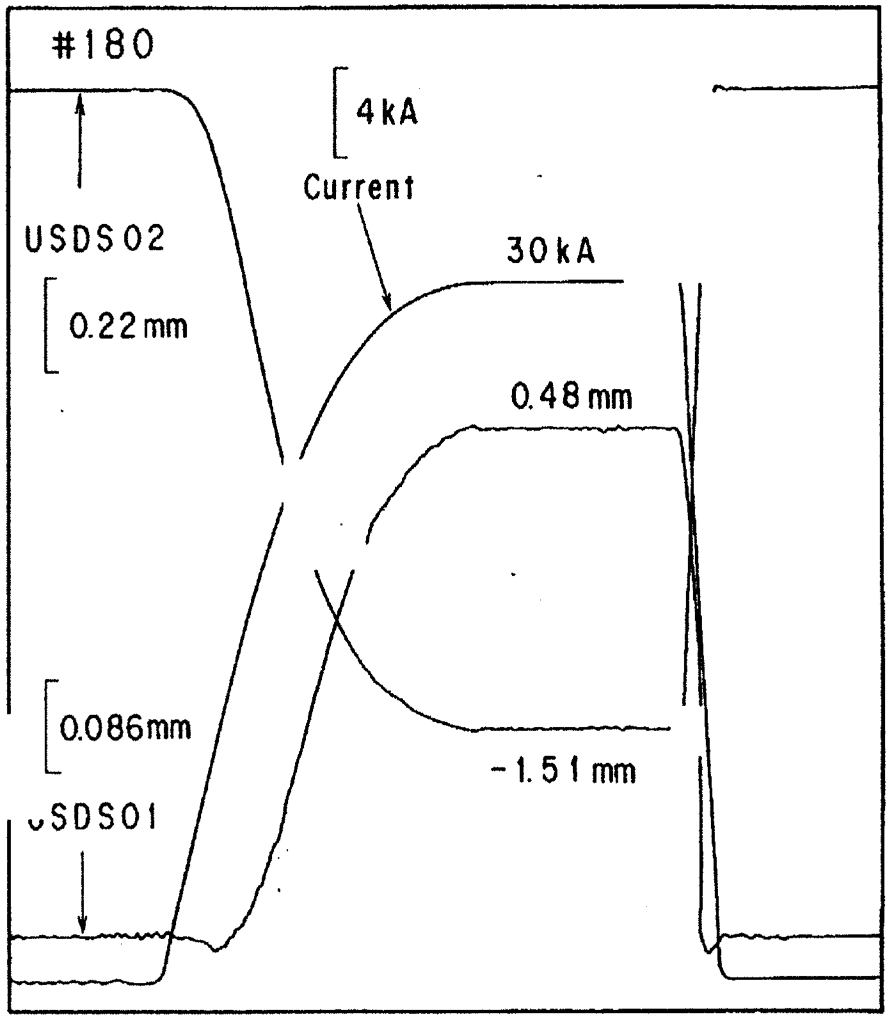


Figure 12.18 - The plots of radial displacement and current are shown for run number 180.

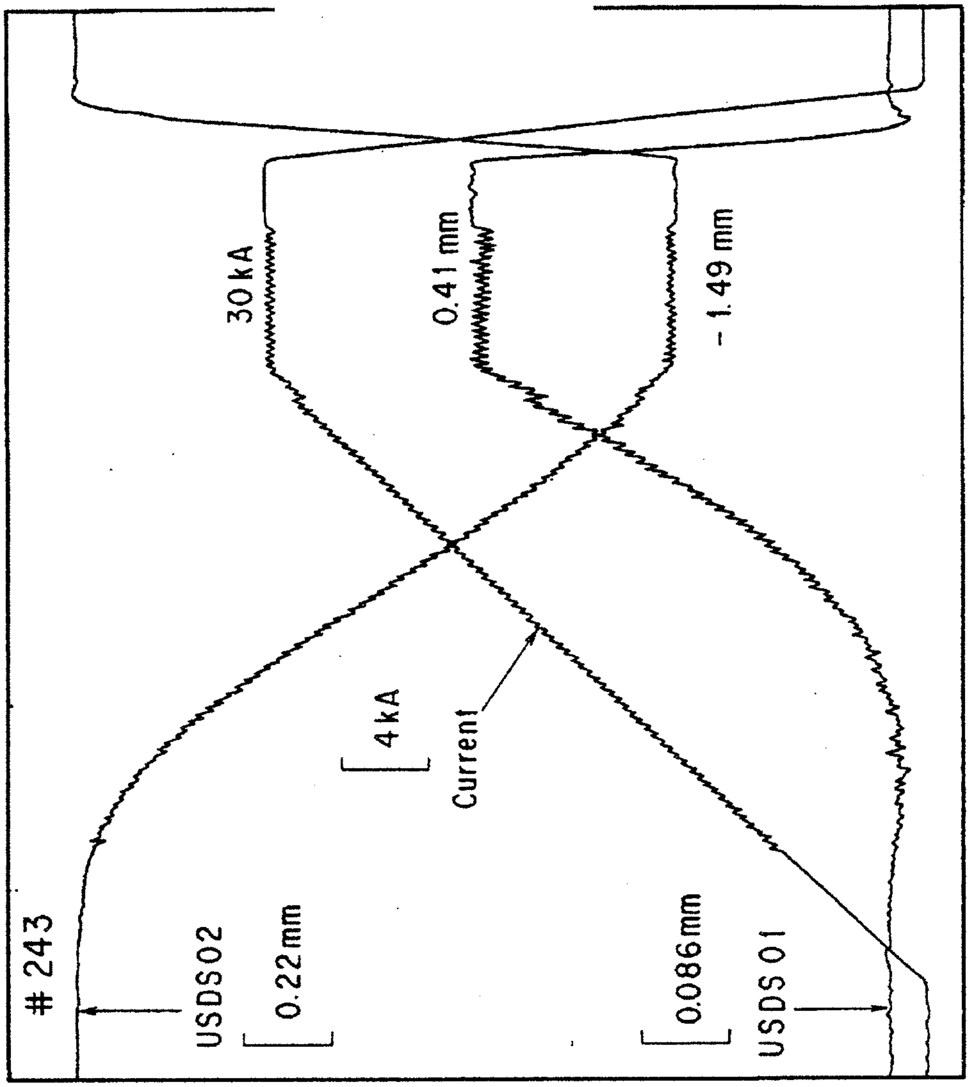


Figure 12.19 - The plots of radial displacement and current are shown for run number 243.

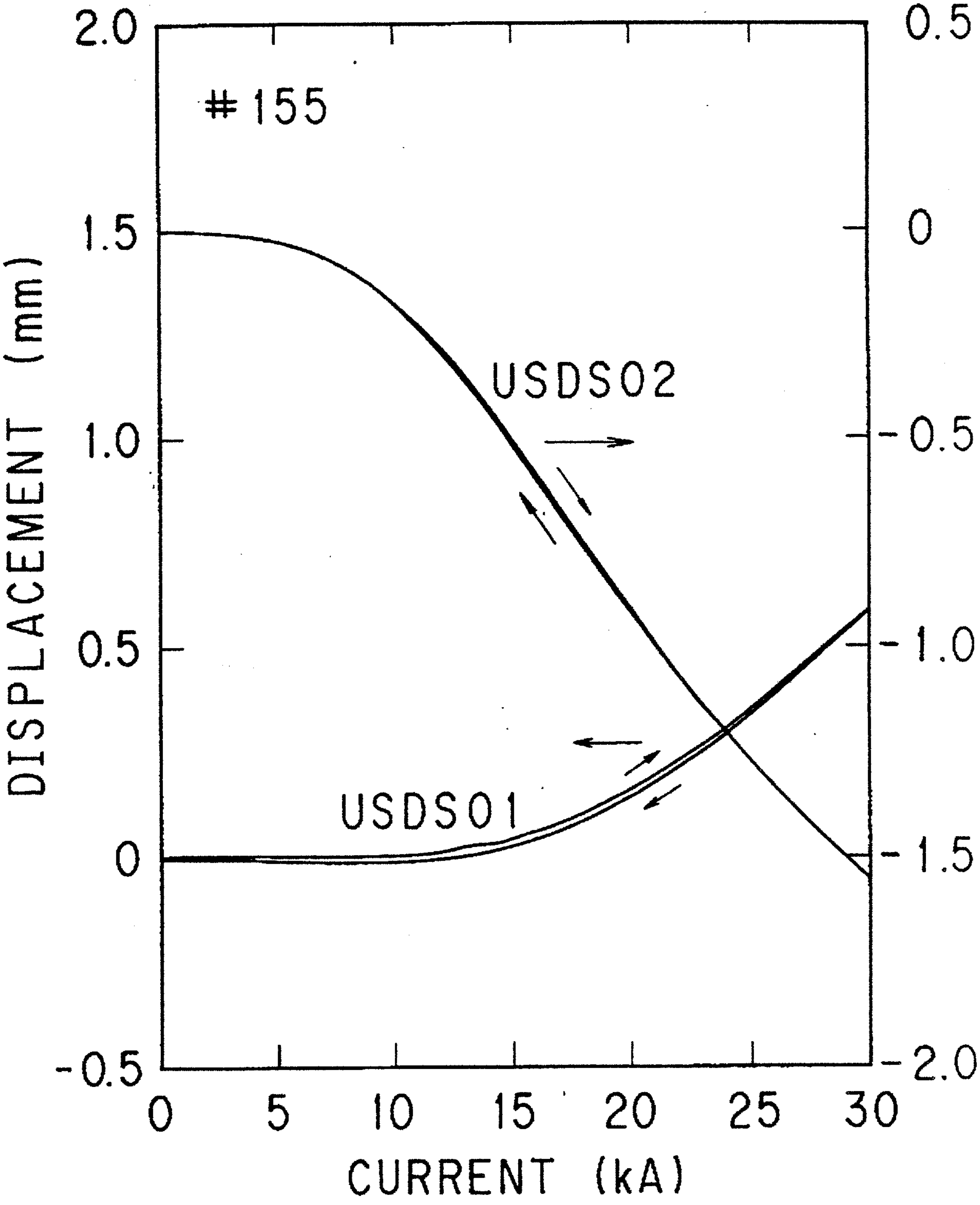


Figure 12.20 - The plots of radial displacement versus current are shown for run number 155. A small hysteresis effect is revealed.

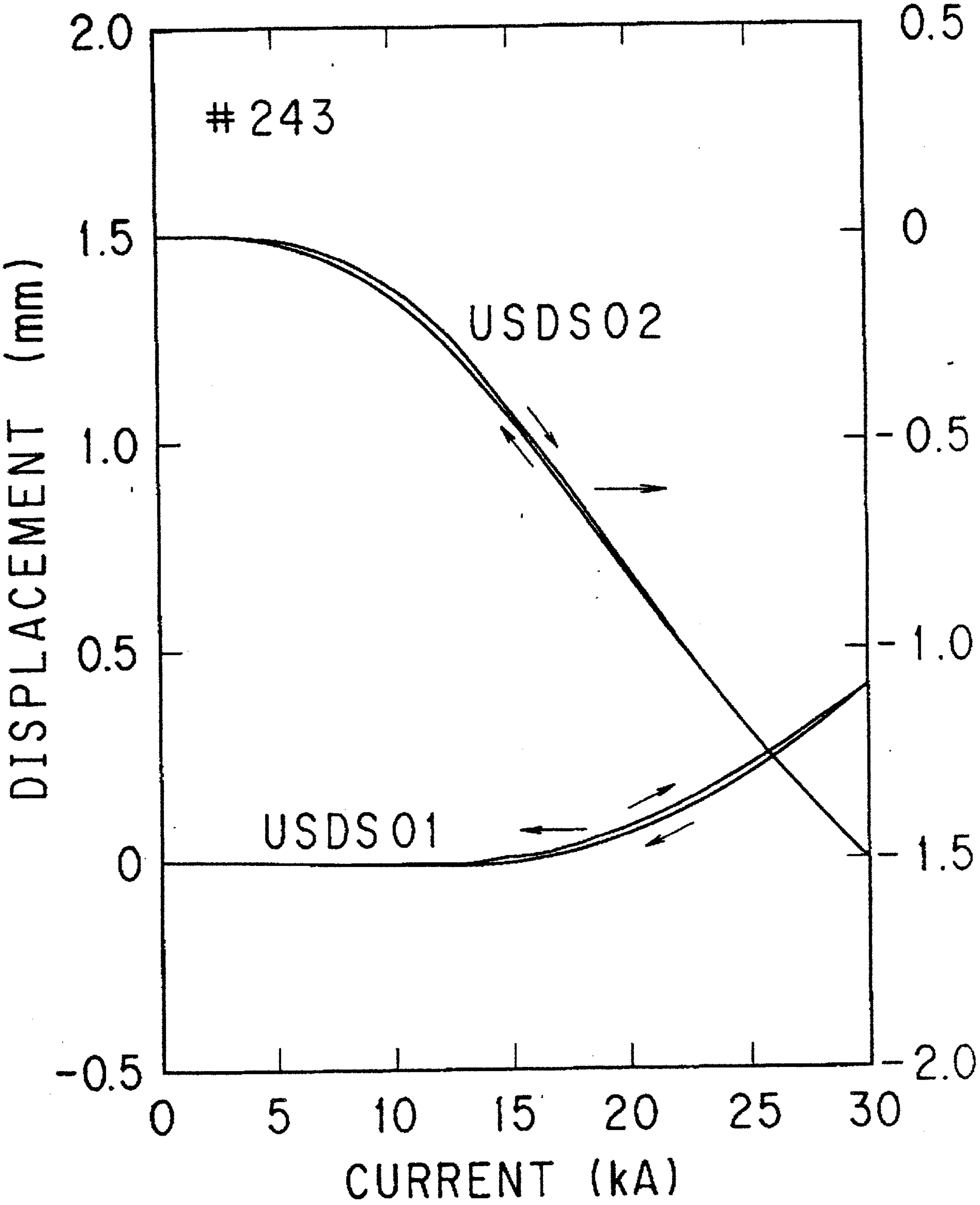


Figure 12.21 - The plots of radial displacement versus current are shown for run number 243. A small hysteresis effect is revealed.

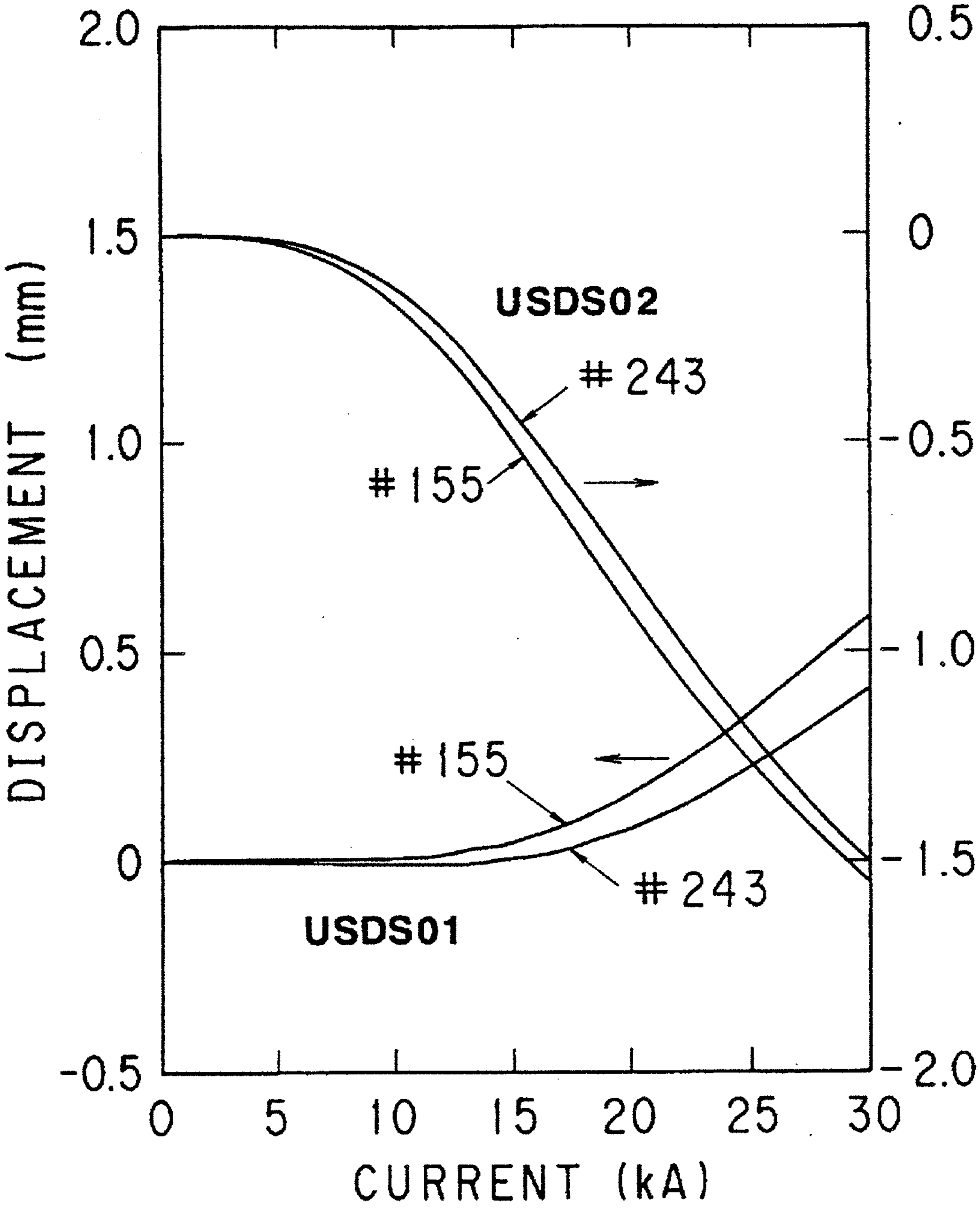


Figure 12.22 - A comparison of the radial displacements of run numbers 155 and 243 show that the measured displacements of run number 155 are larger than the measured displacements of run number 243 for both USDS01 and USDS02.

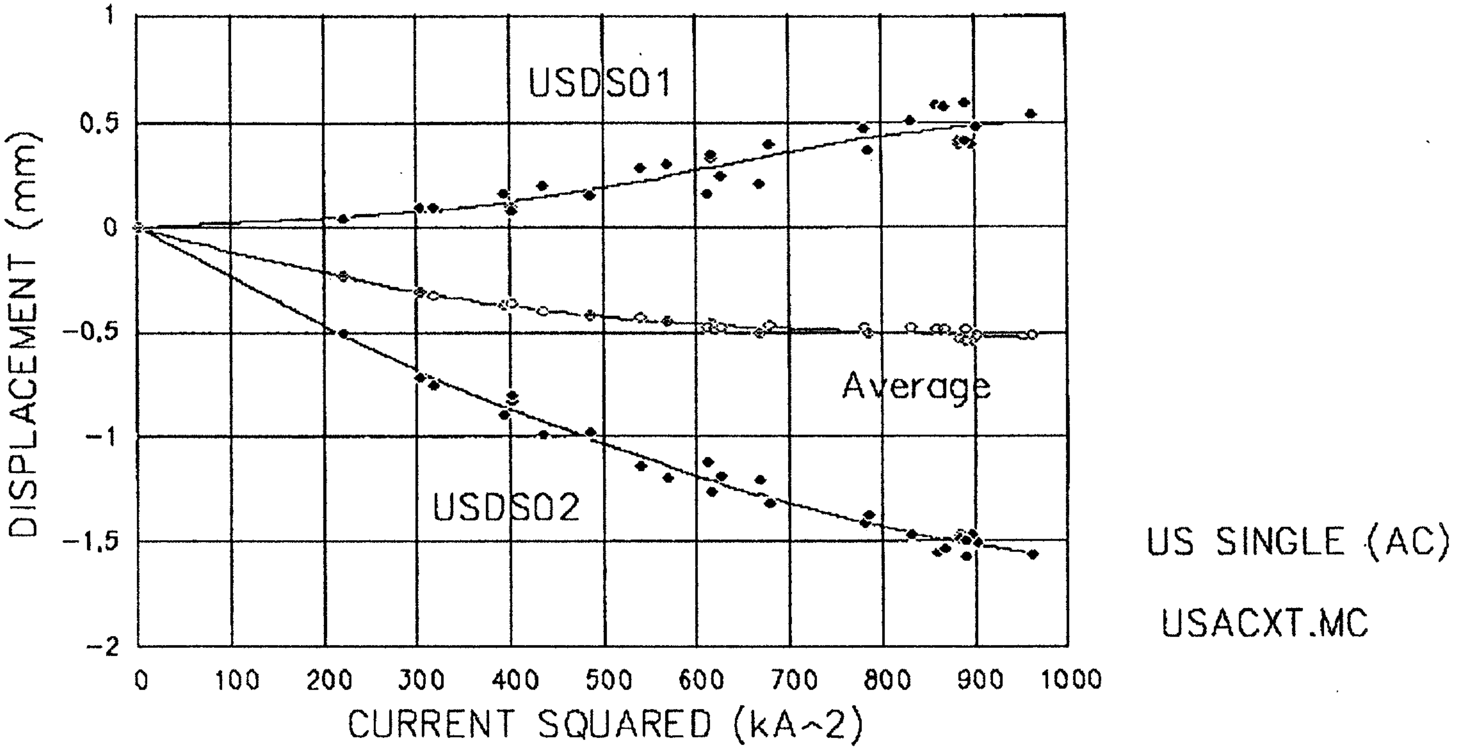


Figure 12.23 - The plots of radial displacement versus current squared are shown for AC tests between run numbers 84 and 251. The maximum average value at 30 kA is about 0.5 mm.

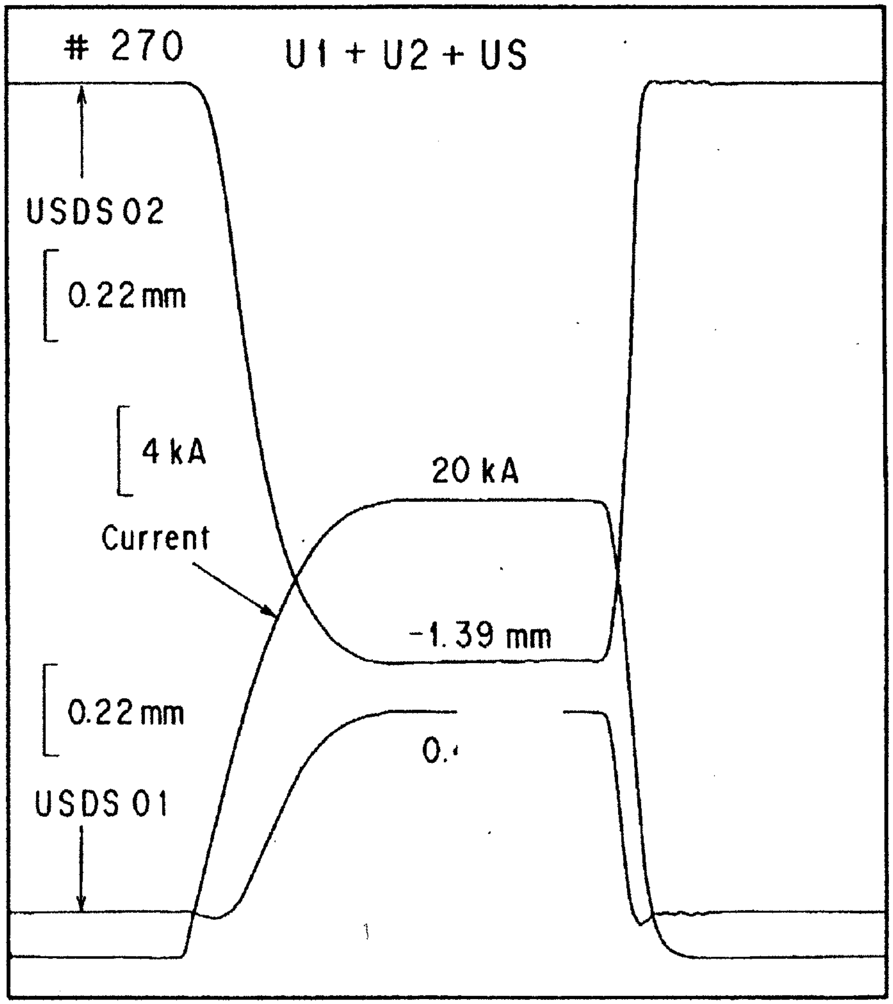


Figure 12.24- The plots of radial displacement and current are shown for run number 270 (series-coil test).

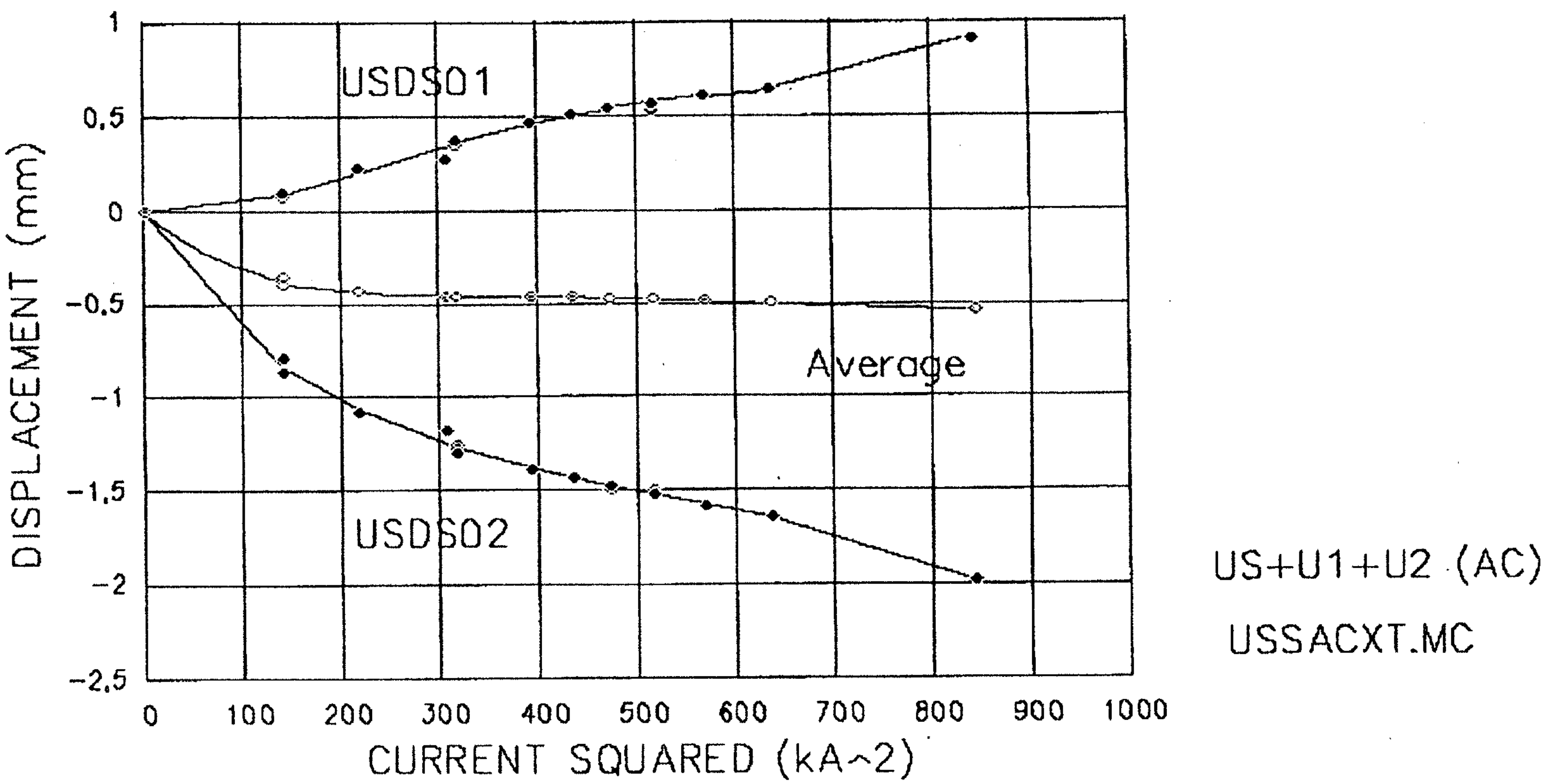


Figure 12.25 - The plots of radial displacement versus current squared are shown for AC tests between run numbers 258 and 278 (series-coil tests). The maximum average value at 30 kA is about 0.5 mm.

12.5. Strain measurements during DC charge tests

12.5.1 Single-coil tests

Figure 12.26 shows measured bolt strains plotted against current squared. In this figure negative values show that the bolts contract. Solid lines are least square regression lines for average values and are in proportion to current squared. The maximum strains of the outside and inside bolts are about 10, -60 ppm, respectively. It is interesting that small positive values were measured in spite of pretensile forces applied to the bolts.

Note that data errors depend on the locations of the bolts. Considering the strain of the same bolt, the data are reproducible and there are few apparent errors as shown in Figure 12.27, which plots bolt strains of STSS13 (outside) and STSS01 (inside) located in the no. 1 structure (see Figure 12.2). Figure 12.28 shows the distribution of bolt strain in the circumferential direction as current increases, with location defined by number as shown in Figure 12.2. It is clear that the scatter shown in Figure 12.26 depends on location.

Figure 12.29 shows the distribution of bolt strain at 30 kA in the circumferential direction. This figure indicates good reproducibility in strain measurements.

12.5.2 Series-coil tests (U1+U2+US)

Figure 12.30 shows measured bolt strains plotted against current squared in series-coil tests, where negative values show that the bolts contract. Solid lines are least square regression lines for average values and are in proportion to current squared. The maximum strains of the outside and inside bolts are about -200, -380 ppm, respectively. The inside value is larger than the outside one. This corresponds to the magnetic force distribution.

As in single-coil tests, data errors depend on the locations of the bolts. Noticing the strain of the same bolt, there are few errors as shown in Figure 12.31, which shows the bolt strains of STSS13 and STSS01.

Figures 12.32 and 12.33 show the distribution of bolt strains in the circumferential direction as current increases. Location is given by sensor number (STSS) as shown in Figure 12.2. Figure 12.34, which plots the bolt strain of STSS01 at 15 kA and 25 kA, shows there was good reproducibility in strain measurements during series-coil tests.

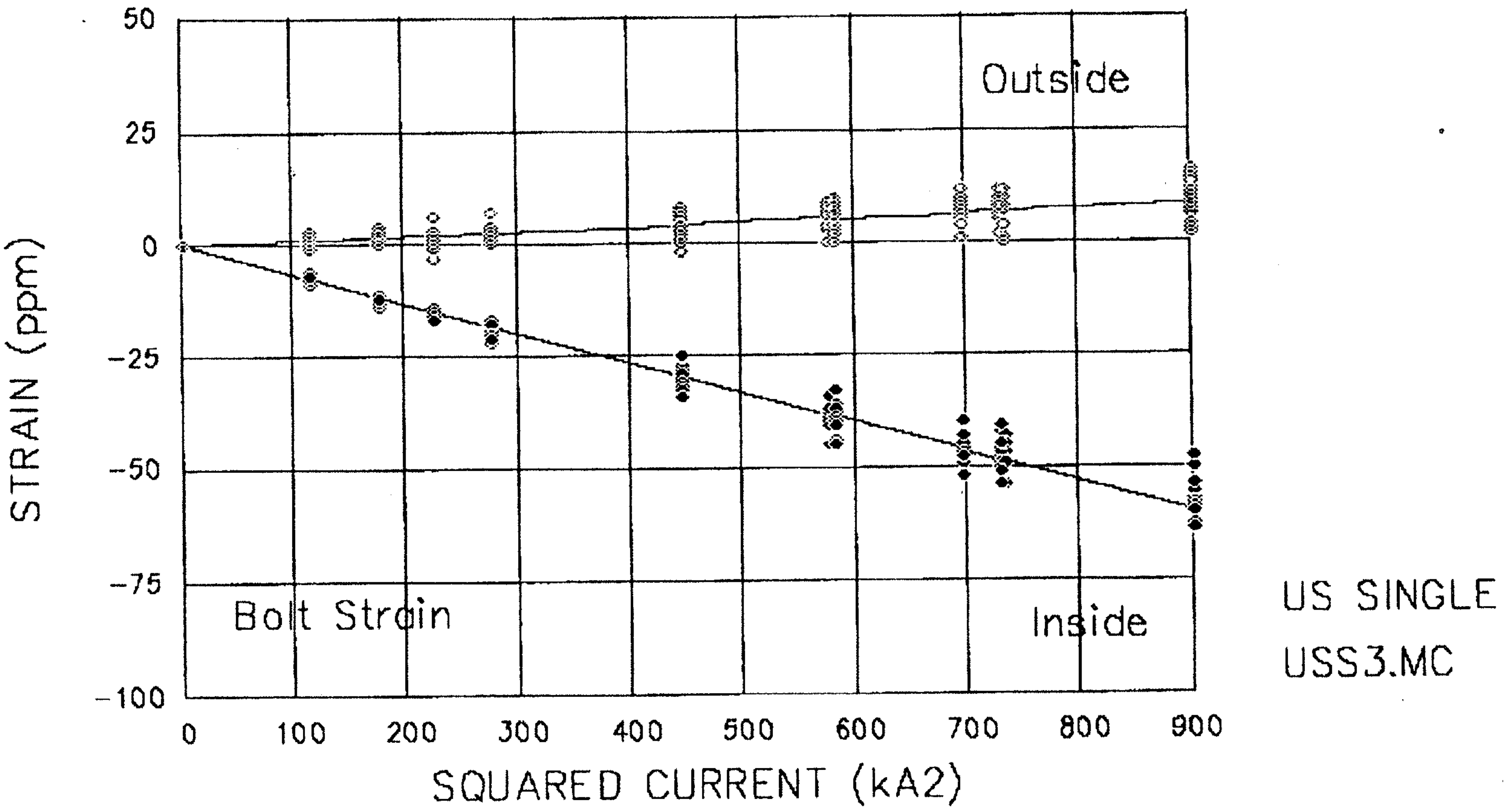


Figure 12.26 - A plot of the measured strain versus current squared during single-coil DC tests show that the strain is proportional to the current squared.

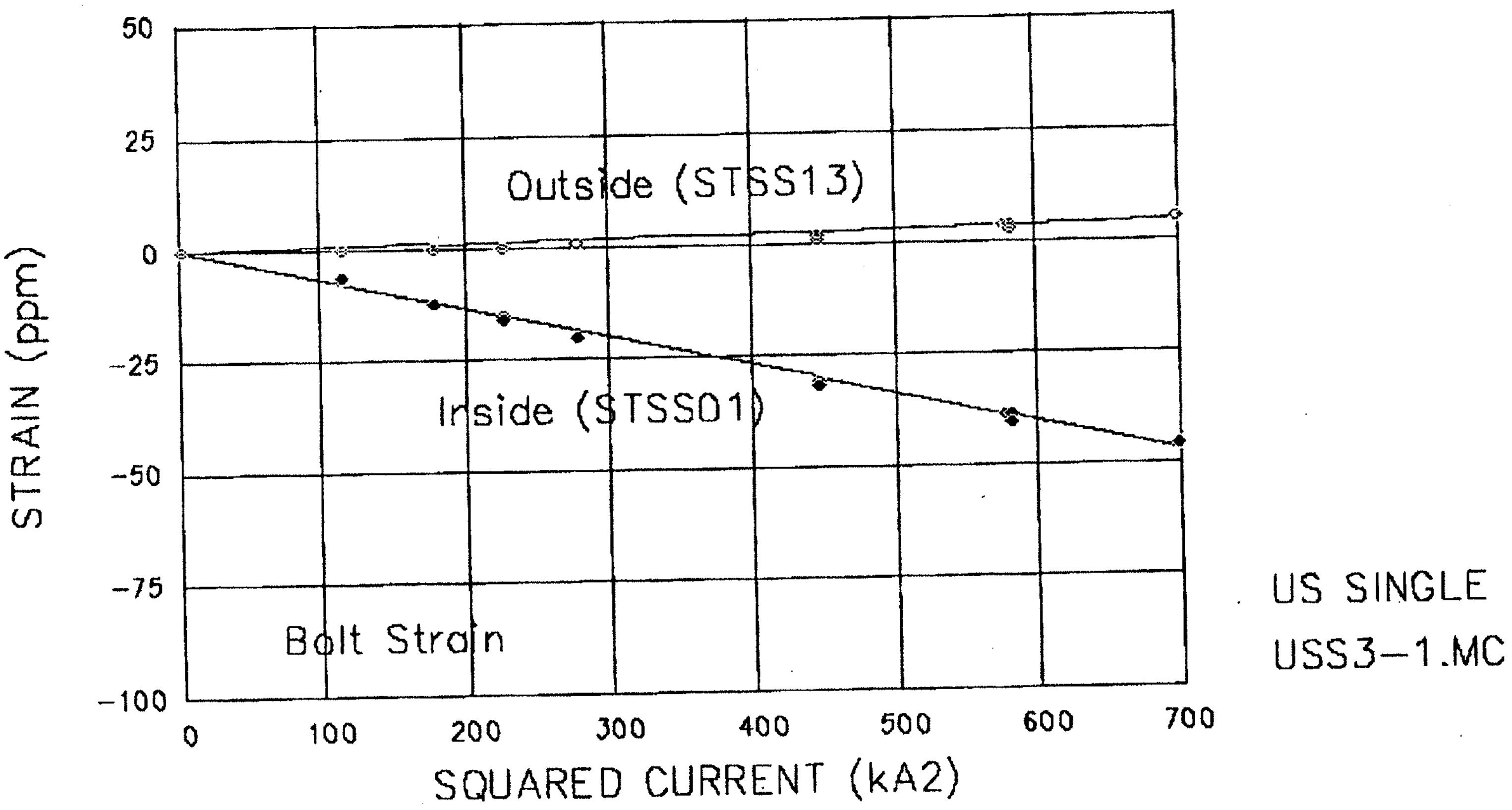


Figure 12.27 - A plot of the measured strain versus current squared during single-coil DC tests for STSS13 and STSS01 show that the strain measurements are reproducible.

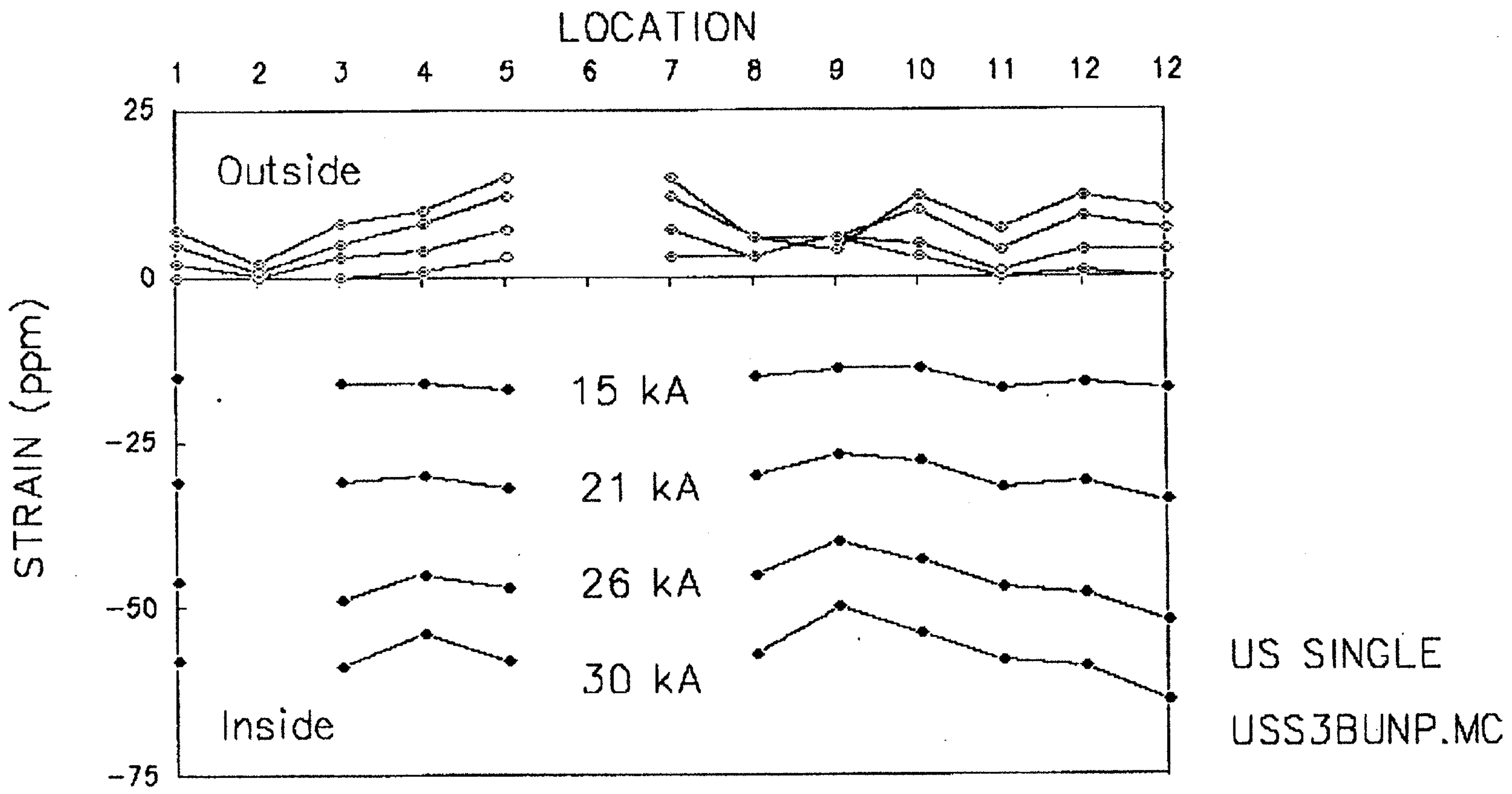


Figure 12.28 - A plot of the bolt strain versus bolt location as the current increases shows that the measurement scatter depends on the measurement location during single-coil tests.

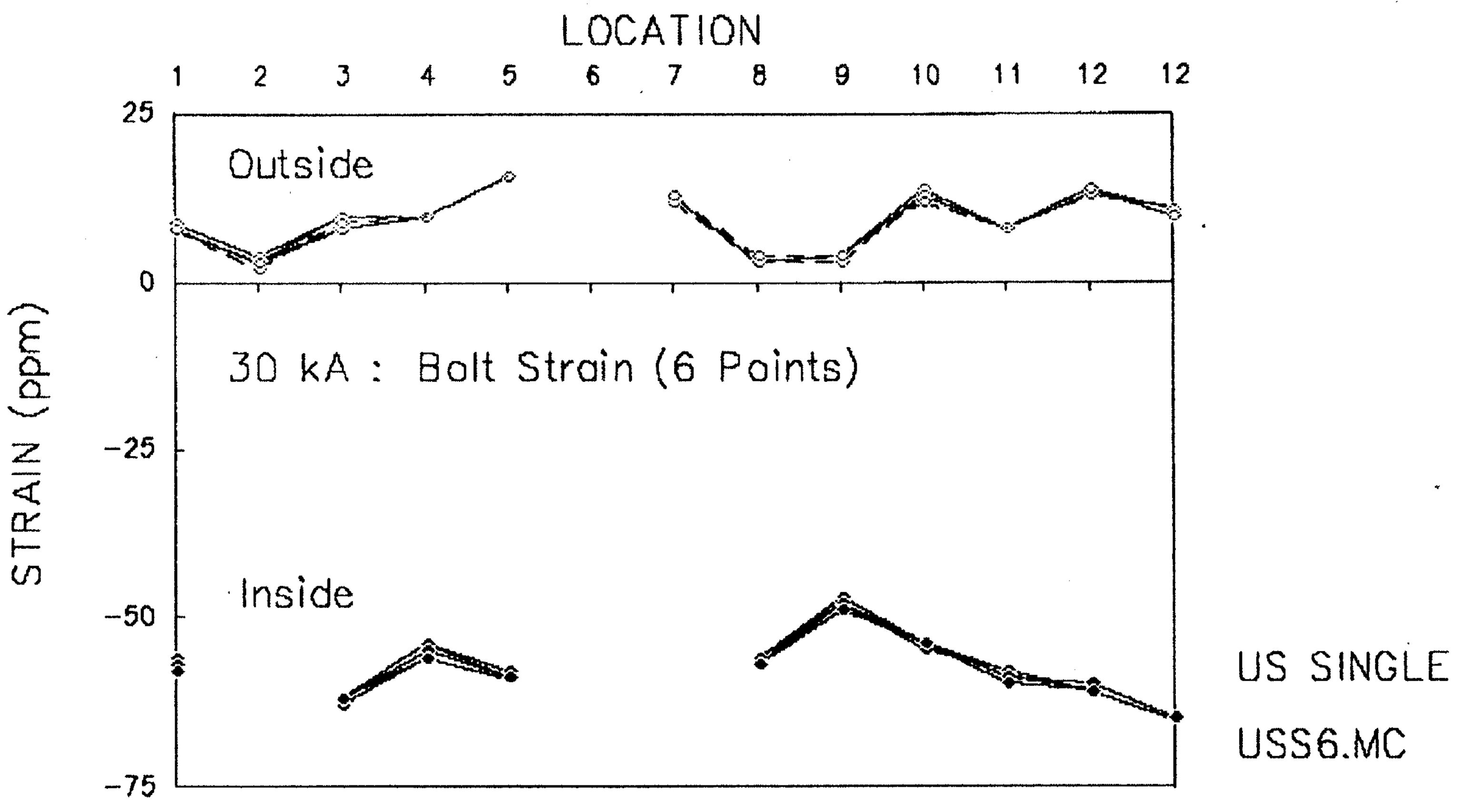


Figure 12.29 - A plot of the measured bolt strains at 30 kA versus bolt location shows good reproducibility of strain measurements during single-coil tests.

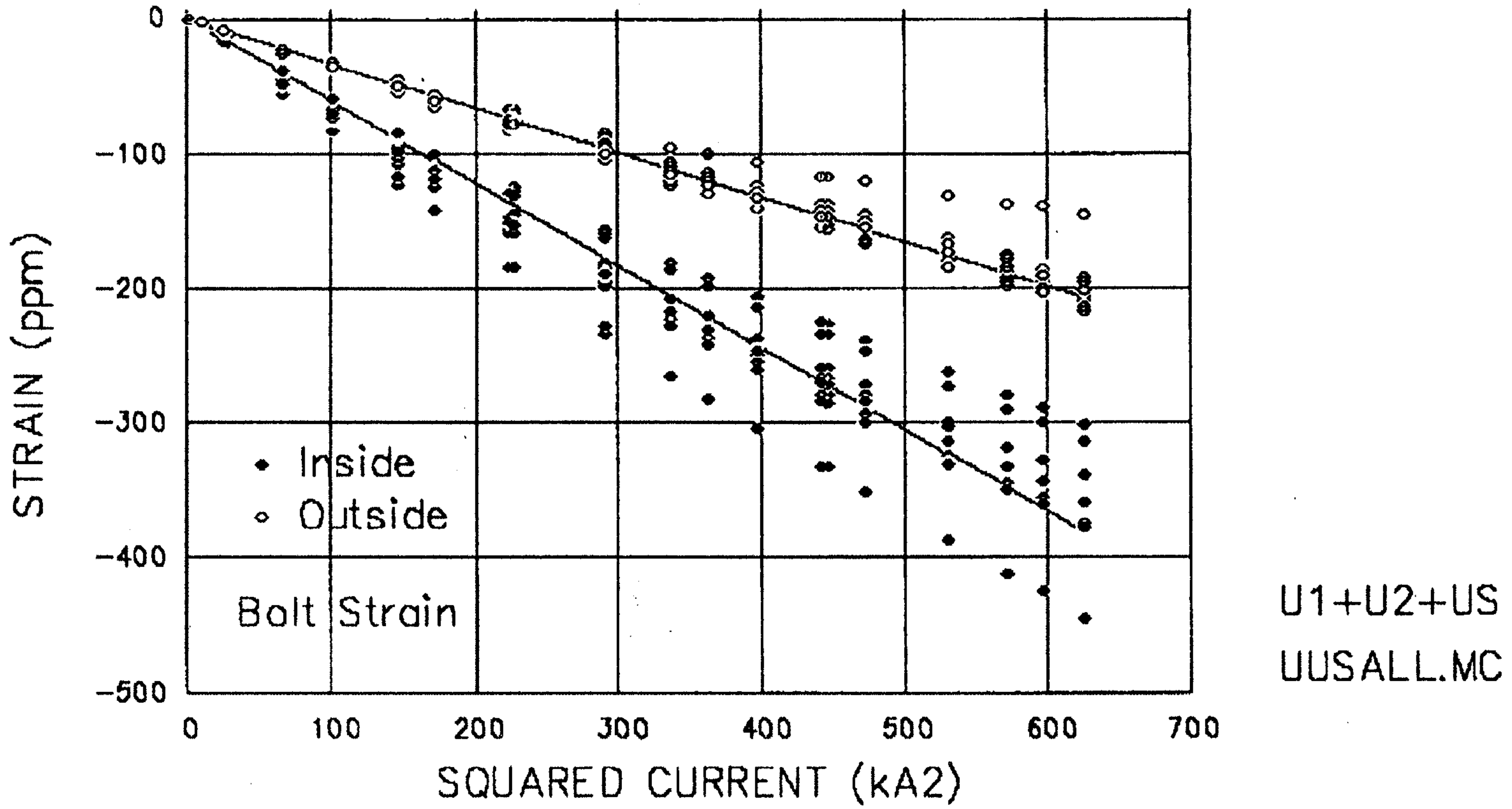


Figure 12.30 - A plot of the measured strain versus current squared during series-coil DC tests shows that the average strain is proportional to the current squared.

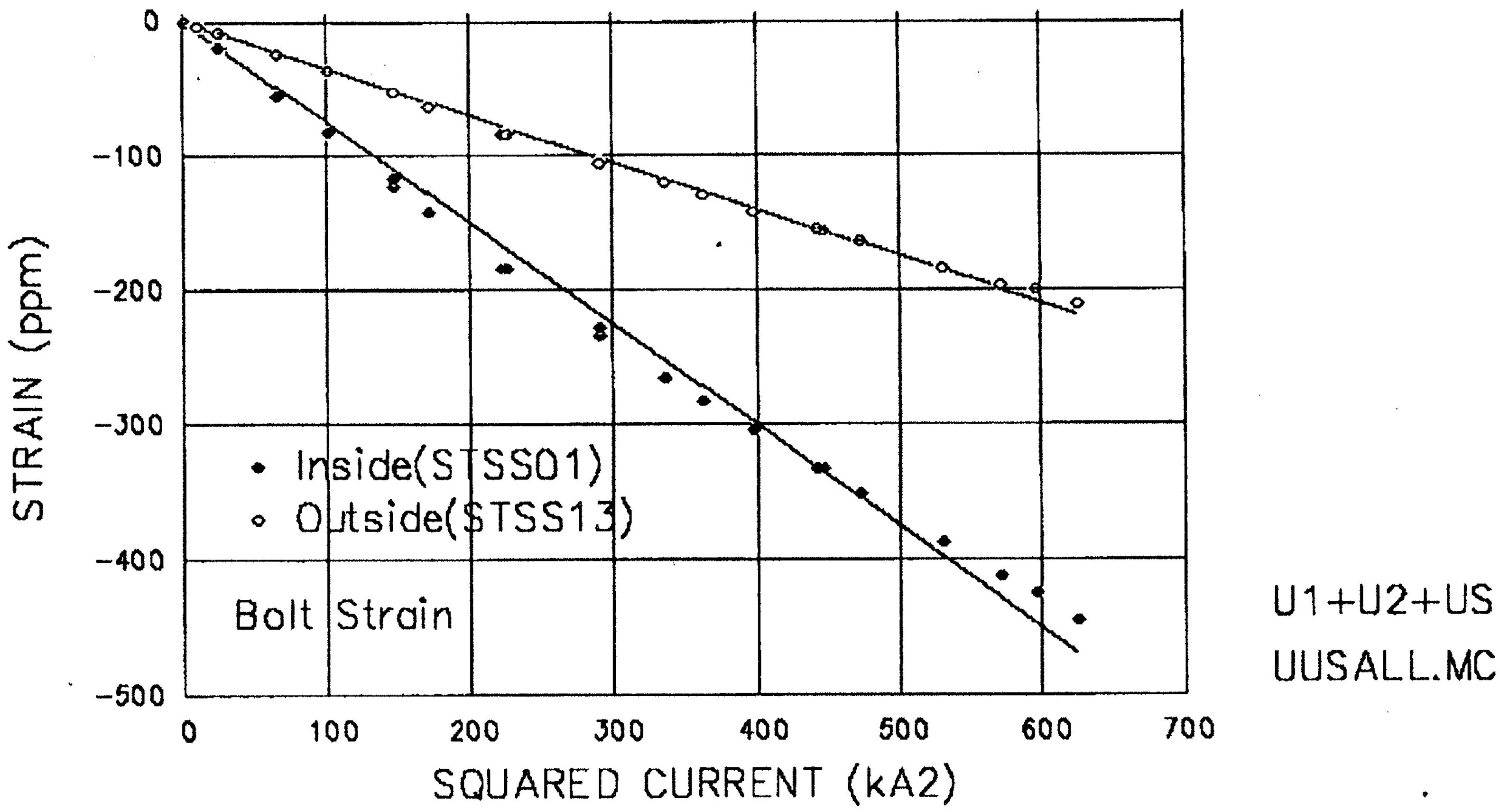


Figure 12.31 - A plot of the measured strain versus current squared during series-coil DC tests for StSS13 and STSS 01.

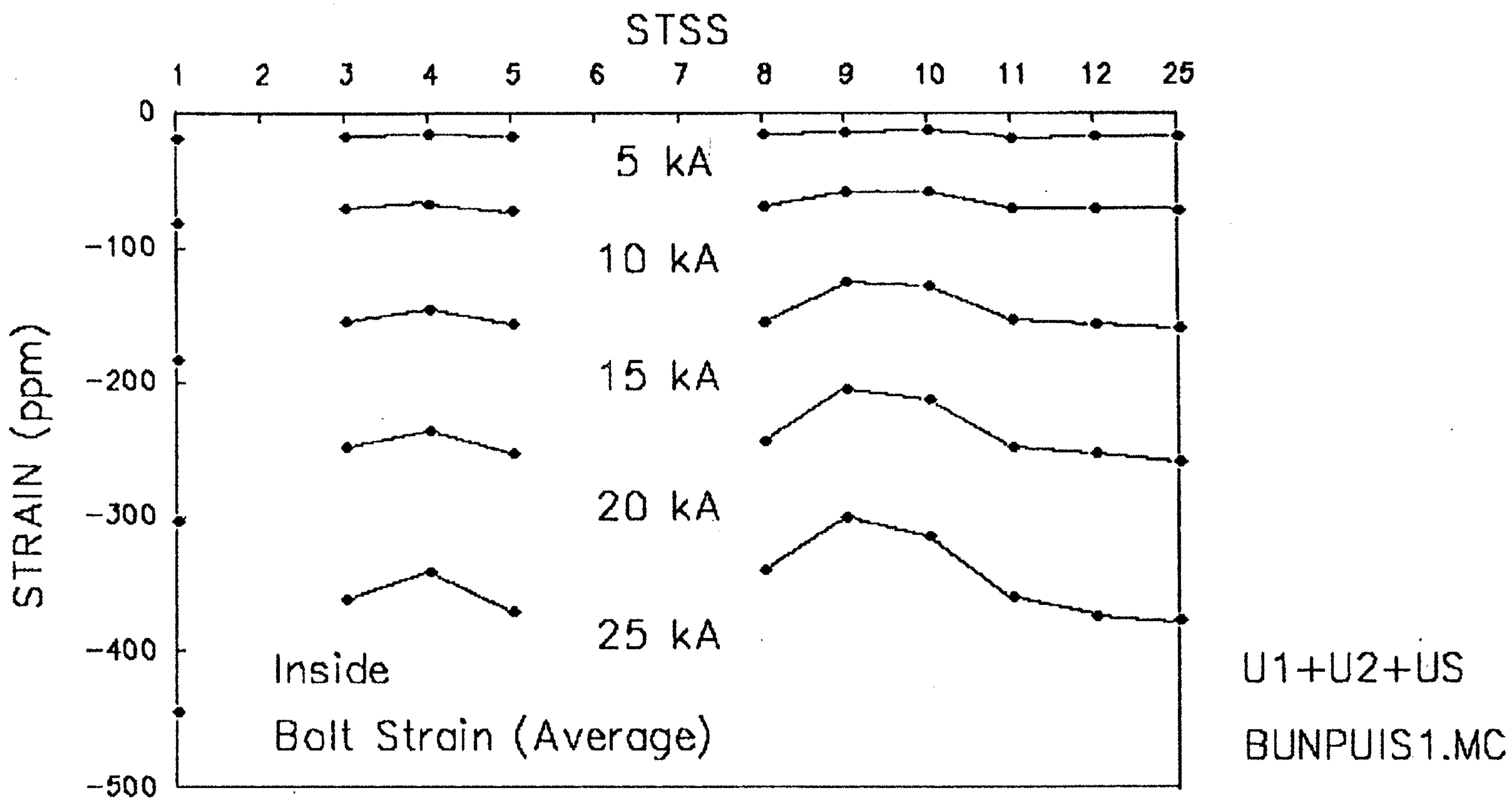


Figure 12.32 - A plot of the inside bolt strain averages versus bolt location as the current increases.

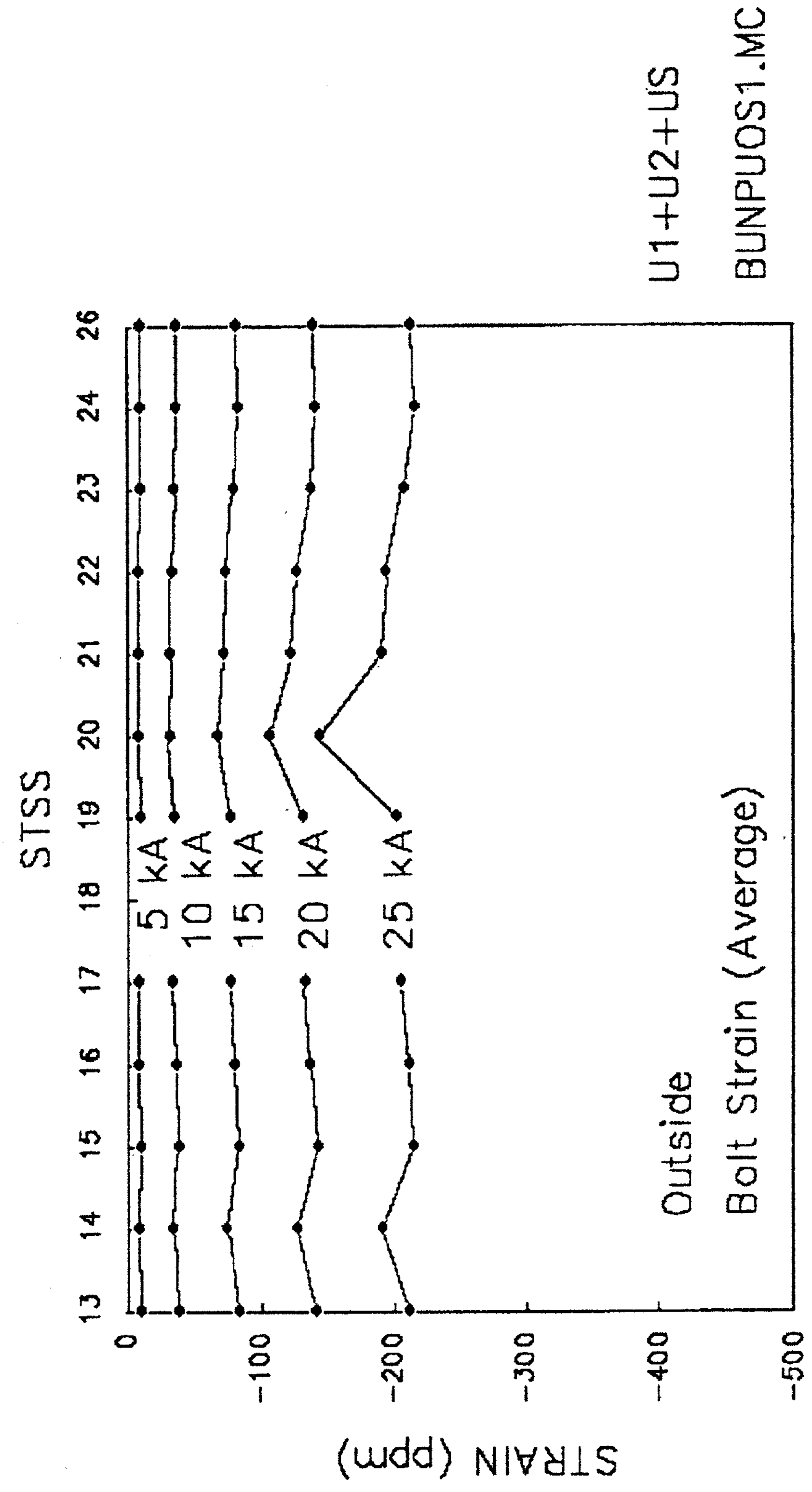


Figure 12.33 - A plot of the outside bolt strain averages versus bolt location as the current increases.

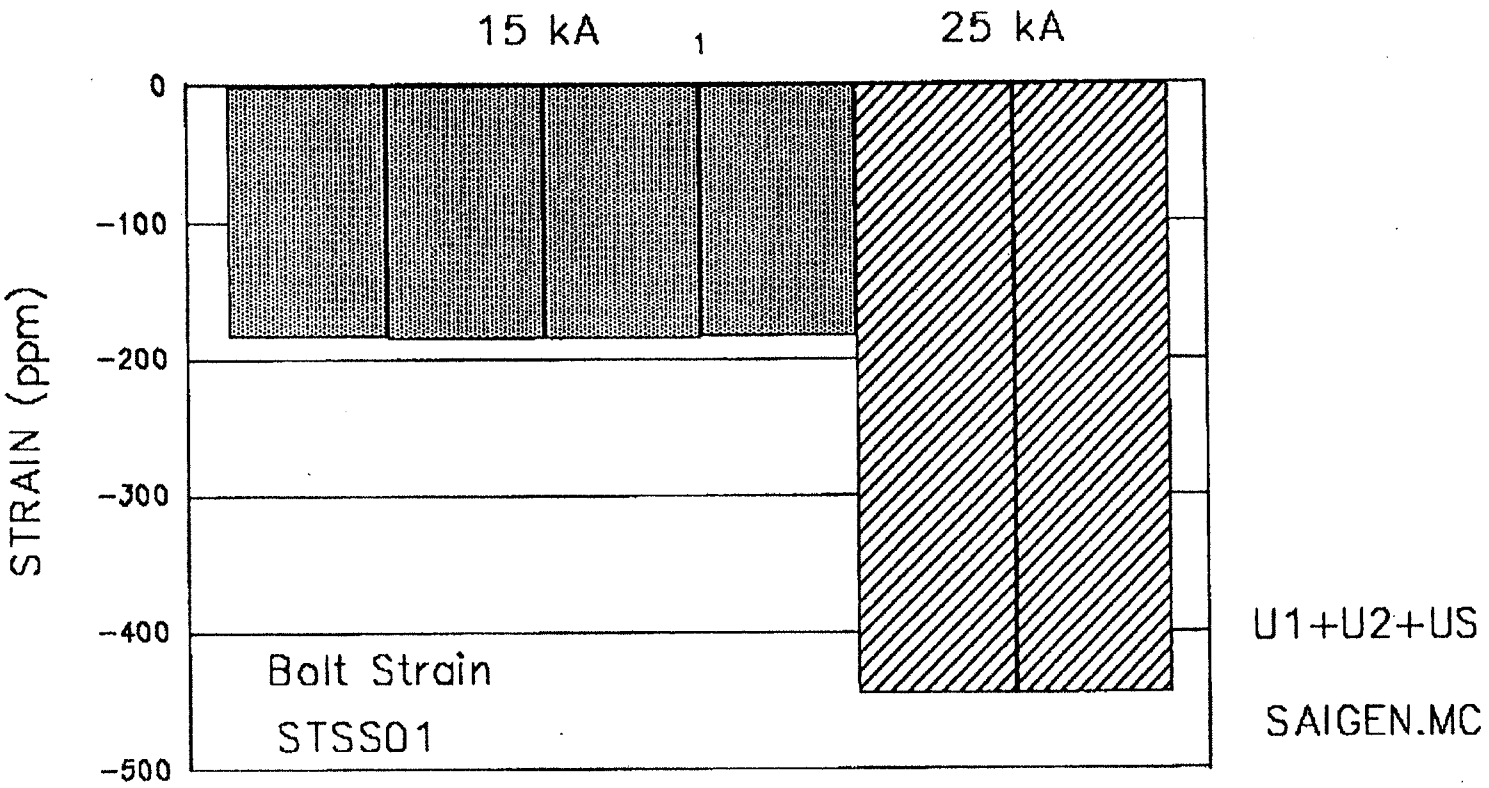


Figure 12.34 - A plot of the measured strain of Bolt STSS01 at 15 kA and 25 kA shows good reproducibility of strain measurements during series-coil tests.

12.6 Summary

The following items summarize the mechanical behavior of the US-DPC during the experiment.

1. Displacements of the coil showed unstable behavior when the coil was charged the first time. Occasional discontinuous displacements that correlated with balance-voltage spikes were observed. However, displacements were stable during all subsequent charges.

2. A small hysteresis effect was observed in the displacement measurements.

3. Measured average displacements were in proportion to current squared up to about 300 kA^2 in single-coil and 200 kA^2 in series-coil tests. Displacements saturated at about 0.45 mm in single-coil and 0.6 mm in series-coil tests.

4. The results of the displacement measurements did not depend on operating mode (DC, AC, single or series) if data scatter was taken into account. The measured average displacements had a scatter within about 0.2 mm. Measured average displacements at 30 kA are shown in Table 12.2.

Table 12.2 -Average displacement at 30 kA as a function of mode.

Mode	Displacement
DC Single	0.45 mm
DC Series	0.6 mm
AC Single	0.5 mm
AC Series	0.5 mm

5. Measured bolt strains were proportional to current squared, with scatter in data from bolt to bolt. In single-coil tests, positive strains were measured in spite of the existence of an applied pretension force on the bolts. A summary of strain measurements is shown in Table 12.3.

Table 12.3 - Average bolt strain at 30 kA as a function of mode.

Mode	Strain	
	Outside	Inside
Single	10 ppm	-60 ppm
Series	-200 ppm	-380 ppm

6. Stable mechanical properties of the US-DPC were demonstrated by good reproducibility of the measured data.

13. Recommendations for future work

Recommendations for future work are as follows:

1. Ramp-rate limitation

The physical mechanism of the ramp-rate limitation and its relationship to limiting current should be clarified and understood. The trigger mechanism of the limitation needs to be identified (flux jumps? wire motion?).

2. Calibration of mass flow meters

All mass flow meters should be calibrated throughout their entire measurement ranges in future large-coil tests. The accuracy of mass flow measurements directly determines the accuracy of AC loss measurements.

3. Joints

A study of the benefits of cooling joints with supercritical versus liquid helium should be made to determine which is the superior choice for poloidal coils. Also, efforts should be directed toward the fabrication of low resistance, low-AC-loss joints.

4. Flow choking

Flow choking and flow unbalances in parallel paths in large coils should be studied. The effects of uneven nuclear and AC loss heating should considered.

5. Current transfer voltages

The perennial question of current transfer between strands of cable-in-conduit conductors should be studied further. The study of current distribution among strands in the cable should be continued.

6. Dual-flow cooling

Dual-flow cooling, in which steady-state heat loads are removed by helium in channels with relatively large hydraulic diameters, should be explored further.

7. Manufacturing process evaluation

Study of the relationship of choices made during coil manufacture to resulting coil performance should continue.

8. AC losses

Studies of the AC losses of superconductors, especially during operation with complex waveforms, should continue.

9. RRR

Studies of the effect of chrome plating on RRR should continue.

Appendix A. Publications associated with the US-DPC

A.1 Annex V

1. John F. Clarke and Yoshinori Ihara, "Annex V to the Implementing Arrangement between the Japan Atomic Energy Research Institute and the United States Department of Energy on Cooperation in Fusion Research and Development for the DOE-JAERI Collaborative Program in the Development of Poloidal Coil Technology," Tokyo, May 19, 1988, available from DOE or the PFC.

A.2 Coil fabrication

2. M.M. Steeves, M.O. Hoenig, J.V. Minervini, C.R. Gibson, M.M. Morra, J. L. Martin, R.G. Ballinger, S. Autler, T. Ichihara, R.Randall, M. Takayasu, and J.R. Hale, "The US-DPC, a Poloidal Coil Test Insert for the Japanese Demonstration Poloidal Coil Test Facility," IEEE Trans. Mag., MAG-24, No. 2, 1307-1310, 1988.

3. M.M. Steeves, M.O. Hoenig, M. Takayasu, R.N. Randall, J.E. Tracey, J.R. Hale, M.M. Morra, I. Hwang, and P. Marti, "Progress in the Manufacture of the US-DPC Test Coil," IEEE Trans. Mag., MAG-25, No. 2, 1738-1741, 1989.

4. M.M. Steeves, T.A. Painter, J.E. Tracey, M.O. Hoenig, M. Takayasu, R.N. Randall, M.M. Morra, I.S. Hwang, and P. Marti, "Further Progress in the Manufacture of the US-DPC Test Coil," MT-ll, 1989.

5. M.M. Steeves, T.A. Painter, M. Takayasu, R.N. Randall, J.E. Tracey, I.S. Hwang and M.O. Hoenig, "The US Demonstration Poloidal Coil," IEEE Trans. Mag. 27, 1991.

A.3 Conductor critical current

6. M. Takayasu, C.Y. Gung, M.M. Steeves, M.O. Hoenig, J.R. Hale and D.B. Smathers, "Critical Currents of Nb3Sn Wires for the US-DPC Coil," IEEE Trans. Mag. 27, 1991.

7. M. Takayasu, M.M.Steeves, T.A.Painter, C.Y.Gung, M.O.Hoenig, "Critical currents of Nb3Sn Wires of the US-DPC Coil," CEC-ICMC conf., Huntsville, AL, June 1991.

A.4 Conductor AC losses

8. M. Takayasu, C.Y. Gung, M.M. Steeves, B. Oliver, D. Reisner and M.O. Hoenig, "Calorimetric Measurement of AC Loss in Nb3Sn Superconductors," MT-11, 1989.

9. C.Y. Gung, M. Takayasu, M.M. Steeves and M.O. Hoenig, "AC Loss Measurements of Nb3Sn Wire Carrying Transport Current," IEEE Trans. Mag. 27, 1991.

10. C.Y. Gung, M.Takayasu, M.M.Steeves, T.A.Painter, B.Oliver, D.Reisner, M.O.Hoenig, "Comparisons of AC losses of Nb3Sn Single Strands and US-DPC Conductor," CEC-ICMC conf., Huntsville, AL, June 1991.

A.5 Low AC loss Nb_3Sn wire development

11. D.B. Smathers, M.B. Siddall, M.M. Steeves, M. Takayasu, and M.O. Hoenig, "Manufacture and Evaluation of Tin Core Modified Jelly Roll Cables for the US-DPC Coil," Adv. in Cryo. Eng, Vol.36 A, Plenum, N.Y., (1990), p. 131.

12. D.B. Smathers, P.M. O'Larey, M.M. Steeves, and M.O. Hoenig, "Production of Tin Core Modified Jelly Roll Cable for the MIT Multipurpose Coil," IEEE Trans. Mag.24, No. 2, 1131-1133, 1988.

A.6 Incoloy 908 development

13. I.S. Hwang, R.G, Ballinger, M.M. Morra, M.M. Steeves and M.O. Hoenig, "Mechanical Properties of Incoloy 908 - An Update," CEC-ICMC conf., Huntsville, AL, June 1991.

14. M.M. Morra, I.S. Hwang, R.G. Ballinger, M.M. Steeves, and M.O. Hoenig, "Effect of Cold Work and Heat Treatment on the 4K Tensile, Fatigue and Fracture Toughness Properties of Incoloy 908," MT-11, 1989.

15. M.M. Morra, R.G. Ballinger, J.L. Martin, M.O. Hoenig, and M.M. Steeves, "Incoloy 908, a New Low Coefficient of Thermal Expansion Sheathing Alloy for Use in ICCS Magnets," Adv.Cryo. Eng., 34, 157-164, 1988.

16. J.L. Martin, M.M. Morra, R.G. Ballinger, M.O. Hoenig, and M.M. Steeves, "Tensile, Fatigue, and Fracture Toughness Properties of a New Low Coefficient of Expansion Cryogenic Structural Alloy, 9XA," Adv.Cryo. Eng., 34., 149-156, 1988.

A.7 Superconducting poloidal coil design

17. M.O.Hoenig and M.M. Steeves,"The Design of a High Field Ohmic Heating Coil for a Superconducting Tokamak based on the US-DPC Test Coil.," IEEE Trans. Mag. 25, 1481-1483, 1989.

18. M.O. Hoenig, M.M. Steeves, and C.R. Gibson, "The Selection of a 30 kA Ohmic Heating Coil Conductor," IEEE Trans. Mag. 24., 1452-1454, 1988.

Appendix B. AC loss measurement technique

B.1 Assumptions

The assumptions made for the AC loss measurement model were as follows:

1. Mass flow was constant at all times. Mass flow did fluctuate for a few seconds during and after a current pulse. However, the integration time in the loss analysis was more than three minutes, and the resultant change in loss energy due to flow fluctuations was negligible.

2. There were no kinetic or potential energy changes.

3. Helium flow was incompressible.

4. All of the heat energy resulting from the current pulse is transported from the coil within times approximately equal to the transit time of the SHe through the CICC. Said more formally, the state throughout the control volume was the same at any two points in time $\tau 1$ and $\tau 2$, if (a) the inlet and outlet conditions at $\tau 1$ are the same as at $\tau 2$, and (b) no current pulse was applied for a time before $\tau 1$ or $\tau 2$ longer than the transit time of the SHe through the CICC.

5. The temperature of inlet supercritical helium (SHe) was constant. This assumption was verified by continuous monitoring of the inlet temperature.

6. Exit SHe temperatures were steady at pre-current-pulse levels approximately one helium transit time after a current pulse. The helium transit time through the 75-meter-long flow passages of the US-DPC was approximately three minutes, corresponding to the time after a current pulse at which the exit temperatures returned to pre-current-pulse levels

7. Pressure was constant at the inlet and outlet at all times. This assumption simplifies the calculation of enthalpy. In reality, the pressure increased to a slightly higher value after a current pulse, but the resultant enthalpy variation was less than 3%.

8. Frictional losses due to short-lived flow fluctuations were negligible. The measurement model accounts for steady-state frictional losses.

B.2 Measurement model

To measure the AC losses, a thermodynamic model of a cable-in-conduit conductor (CICC) was used. The model, shown in Figure B.1, is a single path CICC cooled by supercritical helium and charged with a rapid high-current pulse to induce AC losses. A pump creates SHe flow through the CICC, and return piping passes a heat exchanger cooled by liquid helium, maintaining a constant SHe temperature at the inlet. A control volume is fixed around the following components:

1. Supercritical helium from the CICC inlet to the temperature sensor located at the outlet.
2. The superconducting cable of the CICC.
3. Material other than helium or cable which can conduct away AC loss energy.

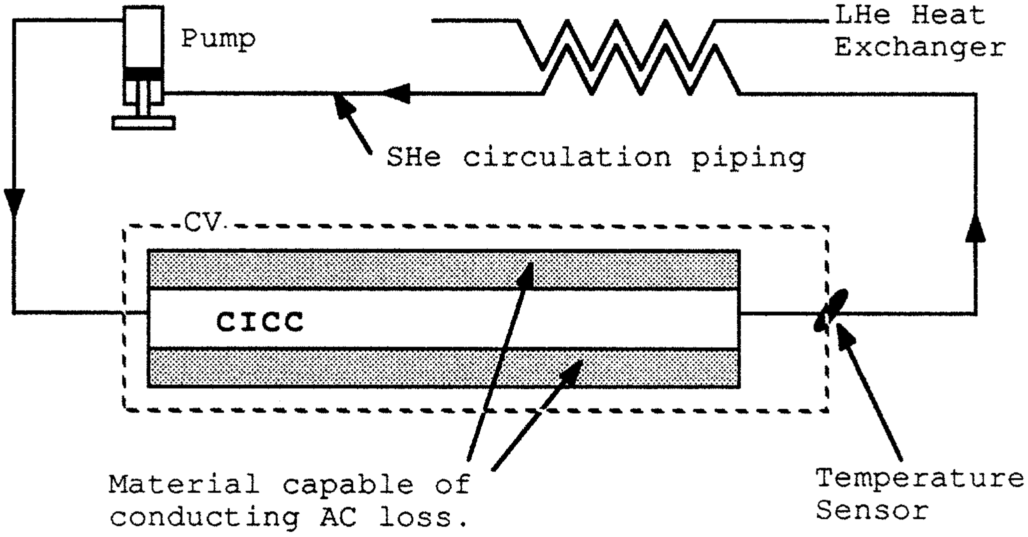


Figure B.1 - Schematic of a model used to find the AC losses of the US-DPC.

After applying Assumptions 1 - 3, the first law for the control volume reduces to Equation B.1, shown being integrated from a time τ_1 just before a current pulse to τ_2 such that $(\tau_2 - \tau_1)$ is greater than the transit time of SHe through the CICC and the temperature at τ_2 has returned to a steady value equal to the temperature at τ_1. The left-hand side of Equation B.1 is the total AC loss

$$\int_{\tau_1}^{\tau_2} \dot{Q}_{AC}\,dt = (E_2 - E_1) + \dot{m}\int_{\tau_1}^{\tau_2} (h_e^t - h_i^t)\,dt + \dot{m}\int_{\tau_1}^{\tau_2} \dot{W}^t\,dt \qquad (B.1)$$

energy created by pulsing the superconductor. The first term on the right-hand side is the difference in energy content of the control volume at τ_1 and τ_2, and due to the choice of integration time, equals zero (see Assumptions 4 - 7). The second term on the right-hand side is the energy flowing into and out of the CICC, and the third term on the right-hand side is the work being done on the control volume. The t superscript is used to denote that the terms apply to a transient period of integration during and after a current pulse.

In order to eliminate the work term in Equation B.1, the First Law is solved for the same control volume during steady state conditions as shown in Equation B.2, where the ss superscript

$$\dot{W}^{ss} = -\,(h_e^{ss} - h_i^{ss}) \qquad (B.2)$$

denotes steady state conditions. The work done to overcome frictional effects is the same during steady state as the work during and after a current pulse (Assumption 8), and as a result Equation

B.2 can be substituted for the work term in Equation B.1.

After applying Assumptions 4 - 8 and substituting Equation B.2, Equation B.1 becomes

$$\int_{\tau_1}^{\tau_2} \dot{Q}_{AC}\, dt = \dot{m} \int_{\tau_1}^{\tau_2} (h_e^t - h_i^t)\, dt - \dot{m} \int_{\tau_1}^{\tau_2} (h_e^{ss} - h_i^{ss})\, dt \qquad (B.3)$$

Finally, the helium enthalpy at the inlet of the CICC is always constant (due to Assumptions 5 and 7), and therefore h_i^t and h_i^{ss} are equal and cancel each other. The reduced equation for the First Law is then given by Equation B.4, which allows the AC loss to be found by measuring only pressure, mass flow and temperature of the outlet SHe between τ_1 and τ_2.

$$\int_{\tau_1}^{\tau_2} \dot{Q}_{AC}\, dt = \dot{m} \int_{\tau_1}^{\tau_2} (h_e^t - h_e^{ss})\, dt \qquad (B.4)$$

B.3 Typical AC loss measurement

By applying the model in Section B.1 to any given flow channel of the US-DPC, we can find the AC loss energy exiting the channel. (Figure 5.9 shows a schematic of the SHe flow channels and sensor locations.) This section presents for run number 122 a typical AC loss measurement performed on the corner flow channel of pancake 3.

As derived in the previous section, the AC loss energy exiting the CICC can be found from Equation B.4. The temperature measurement resulting from the current pulse of Figure B.2 is shown in Figure B.3. (Note that the trigger times for the data in Figures B.2 and B.3 are not the same.) From the measurement of the outlet temperature and pressure (constant at 5.2 atmospheres absolute), the enthalpy in Equation B.4 can be found from thermodynamic tables.

Figure B.4 shows the exit enthalpy calculated by computer at each temperature data point. Part (a) of Figure B.4 shows the total outlet enthalpy as a function of time, and part (b) subtracts the steady state enthalpy from the total enthalpy to find the AC loss energy as a function of time. Part (b) is then integrated by computer and multiplied by the mass flow to find the AC loss exiting the channel. The same procedure is used on the remaining flow channels of the US-DPC and summed to find the total AC loss of each run.

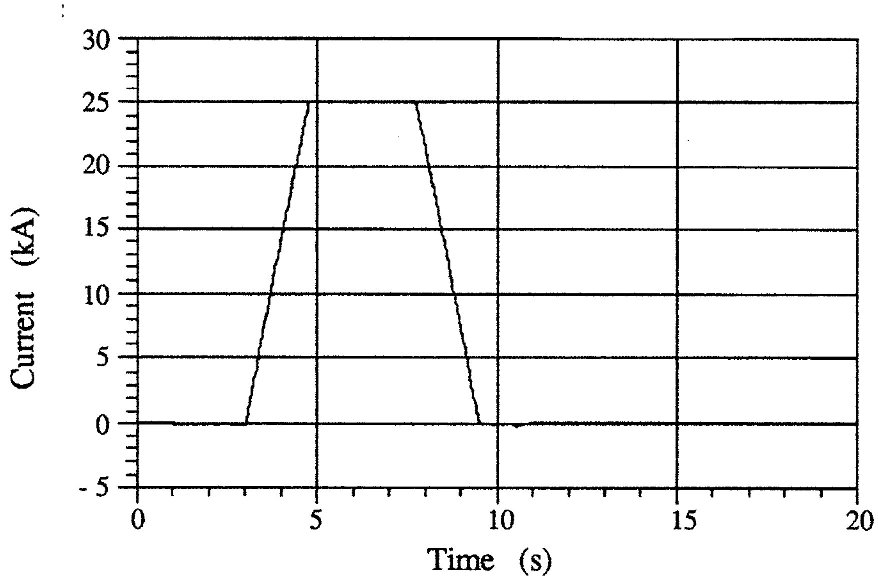


Figure B.2 - The current pulse applied to the US-DPC for run number 122 is shown. The parameters of the current pulse are as follows.

Flat top current = 25 kA (corresponding to a maximum field of 4.73 Tesla)
Ramp-up time = 1.75 seconds
Ramp-down time = 1.75 seconds
Flat top time = 3.0 seconds

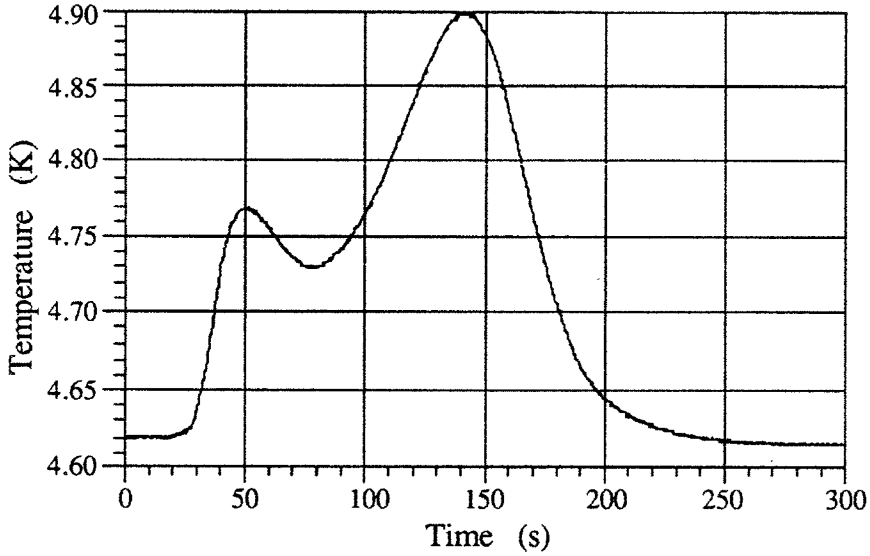
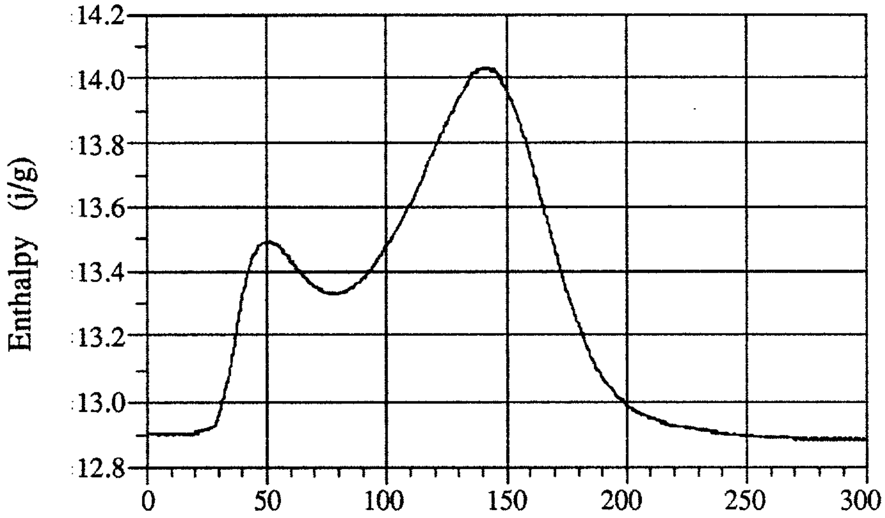
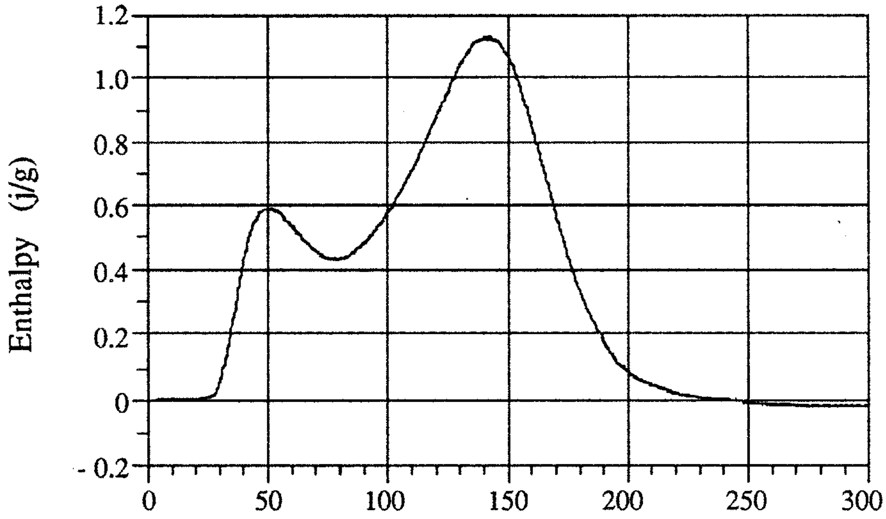


Figure B.3 - The above measurement shows the SHe temperature as it exits the corner flow channel of pancake 3 for run number 122.



(a) total enthalpy (h_e^t) exiting the corner flow channel of pancake 3 for run number 122.



(b) AC loss portion (h_e^t - h_e^{ss}) of the enthalpy shown in part (a)

Figure B.4 - The enthalpy of the exit SHe is found from the temperature profile and pressure of the exit SHe. Part (a) shows the total enthalpy as a function of time (h_e^t) exiting the corner flow channel of pancake 3, and part (b) shows the AC loss portion (h_e^t - h_e^{ss}) of the enthalpy shown in part (a).

B.4 Pressure and mass flow measurements of example

This section provides the inlet and outlet pressures and mass flows of the corner flow channel of pancake 3 for run 122 (Figures B.5 - B.8) for the reader's reference. The inlet temperature measurements during the run were constant. Also, the pressures, mass flows and temperatures were monitored continuously at long times before and after each run to insure that the conditions remained steady in accordance with the assumptions. The trigger times for the data in Figures B.2, B.7 and B.8 are the same. However, the trigger times for the data in Figures B.5 and B.6 differ from the other graphs.

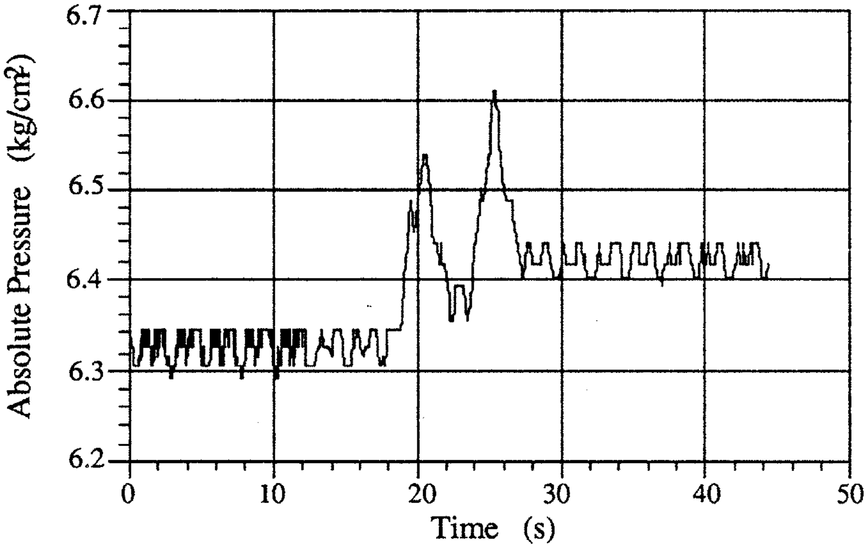


Figure B.5 - The pressure at the inlet of double pancake B shows the slight rise that results from the current pulse of run 122. The current pulse begins at about the 19 second mark (1 kg/cm^2 = 0.968 atmosphere).

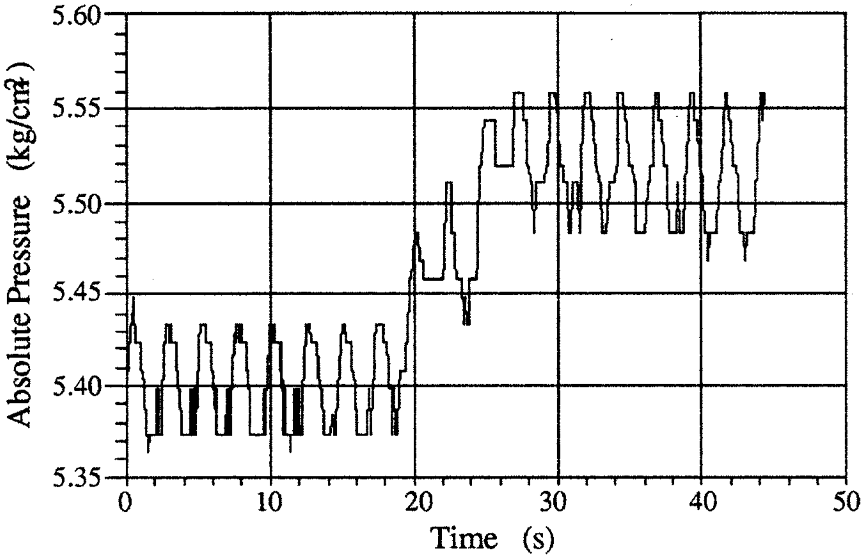


Figure B.6 - The pressure at the outlet of the corner flow channel of pancake 3 shows the slight rise resulting from the current pulse of run 122. The current pulse begins at about the 19 second mark (1 kg/cm^2 = 0.968 atmosphere).

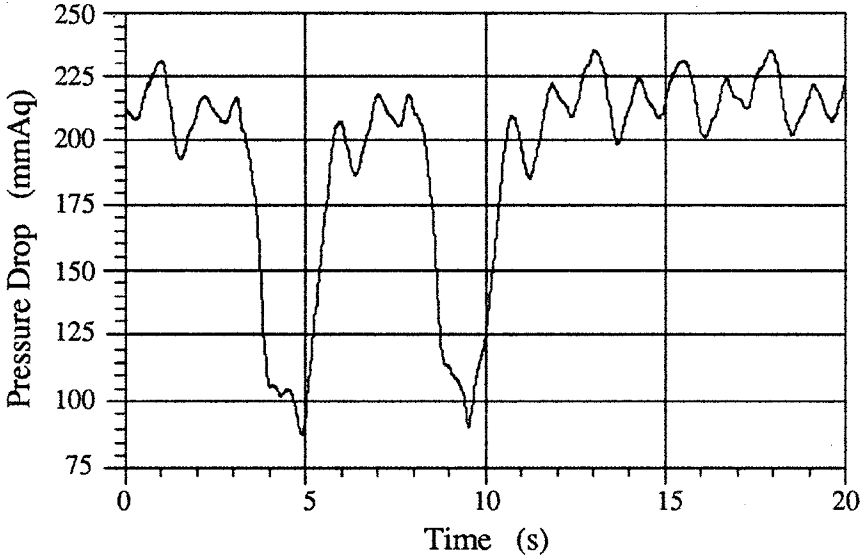


Figure B.7 - The mass flow at the inlet of double pancake B reveals the choking reaction to the current pulse of run 122. The equation for converting ΔP to mass flow is $\dot{m}\,(g/s) = 2.36\sqrt{\rho(g/cm^3) \times \Delta P\,(mmAQ)}$

Helium density is approximately 0.140 g/cm^3.

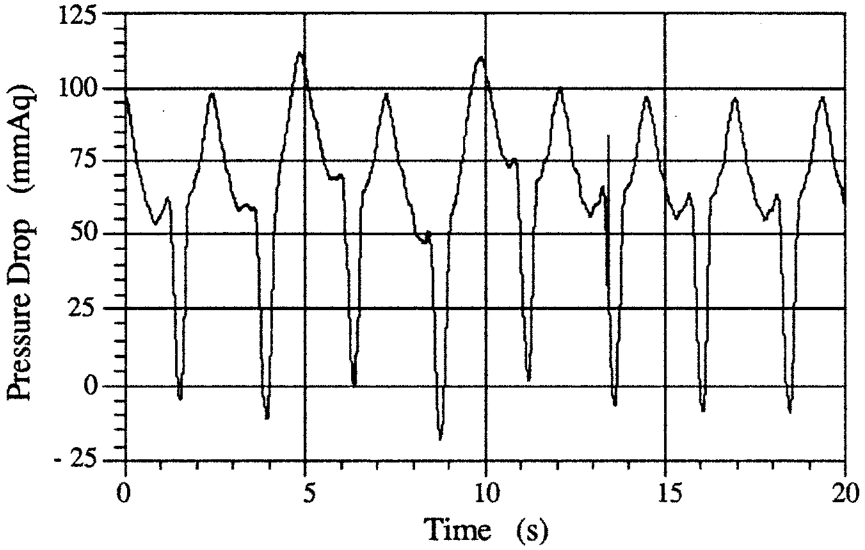


Figure B.8 - The mass flow at the outlet of the corner channel of pancake 3 reveals the choking reaction to the current pulse of run 122. The equation for converting ΔP to mass flow is $\dot{m}\ (g/s) = 1.18\sqrt{\rho(g/cm^3) \times \Delta P\ (mmAQ)}$ Helium density is approximately 0.140 g/cm^3.

Appendix C. Table of losses of AC test runs

AC Losses of Double Pancake B (single-coil tests) part 1 of 3

Run No.	Charging Pattern	I_{max} (kA)	B_{max} (T)	T_m (S)	AC Loss (kJ)	inlet flow (g/s)	inlet temp. (K)	inlet press. (absolute) (atm.)
74	triangle	1.5	0.284	5	-----	-----	-----	5.929
75	triangle	1.5	0.284	5	-----	-----	4.75	5.861
77	triangle	1.5	0.284	5	-----	-----	4.74	5.977
78	triangle	1.5	0.284	0.5	-----	-----	4.75	6.050
79	triangle	1.5	0.284	0.5	-----	-----	4.75	6.050
80	triangle	6	1.134	0.5	247	12.36	4.74	6.098
81	triangle	6	1.134	0.5	234	12.37	4.74	6.118
82	triangle	12	2.268	0.5	548	12.34	4.75	6.142
83	triangle	18	3.402	0.5	897	12.36	4.75	6.142
84	triangle	18	3.402	0.5	-----	12.34	4.75	6.074
85	triangle	24	4.536	0.5	1389	12.42	4.74	6.074
86	triangle	24	4.536	0.5	1388	12.37	4.74	6.118
87	triangle	27	5.103	0.5	1833	12.44	4.75	6.098
88	triangle	30	5.670	0.5	3680	13.94	4.75	6.118
89	triangle	28.5	5.387	0.5	2240	12.32	4.74	6.074
90	triangle	1.5	0.284	5	-----	-----	4.74	6.239
91	triangle	1.5	0.284	5	-----	-----	4.74	6.287
92	triangle	29	5.481	0.5	2290	12.61	4.74	6.331
93	triangle	29	5.481	0.5	2550	12.66	4.74	6.287
96	triangle	29	5.481	0.5	2310	12.64	4.73	6.239
97	trapezoid	12	2.268	0.5	566	12.60	4.73	6.287
98	trapezoid	18	3.402	0.5	983	12.61	4.74	6.355
100	trapezoid	21	3.969	0.5	1324	12.65	4.74	6.239
101	trapezoid	15	2.835	5	598	12.55	4.73	6.331
102	trapezoid	15	2.835	2	618	12.56	4.73	6.355
103	trapezoid	15	2.835	1.5	636	12.65	4.73	6.355
104	trapezoid	15	2.835	1	671	12.58	4.73	6.355
105	trapezoid	15	2.835	0.75	701	12.67	4.73	6.403
106	trapezoid	15	2.835	0.5	754	12.65	4.73	6.287
107	trapezoid	15	2.835	0.3	865	12.64	4.73	6.311
108	trapezoid	20	3.780	1.5	1029	12.49	4.73	6.331
109	trapezoid	20	3.780	5	790	12.57	4.73	6.331
110	trapezoid	20	3.780	2	848	12.57	4.73	6.331
111	trapezoid	20	3.780	1	975	12.63	4.73	6.287
112	triangle	1.5	0.284	5	-----	-----	4.73	6.142
113	triangle	1.5	0.284	5	-----	-----	4.73	6.166
114	trapezoid	20	3.780	0.75	1213	13.01	4.72	6.190
115	trapezoid	20	3.780	0.5	1359	13.05	4.73	6.190
116	trapezoid	20	3.780	0.3	1652	13.07	4.73	6.190
117	trapezoid	25	4.725	6	-----	-----	4.73	6.166
118	trapezoid	25	4.725	6	1111	12.80	4.73	6.166
119	trapezoid	25	4.725	3	1185	12.80	4.73	6.166
120	trapezoid	25	4.725	2	1267	13.05	4.73	6.142
122	trapezoid	25	4.725	1.75	1346	13.03	4.73	6.142
123	trapezoid	30	5.670	11	2280	12.28	4.74	6.142
124	trapezoid	30	5.670	8	2390	12.01	4.74	6.166
127	trapezoid	22	4.158	1	1360	13.15	4.75	6.098
128	trapezoid	23	4.347	1	1538	13.10	4.78	6.524
131	trapezoid	31	5.859	11	-----	12.41	4.73	6.026
132	trapezoid	23	4.347	1	-----	13.53	4.34	6.166
134	trapezoid	32	6.048	11	2500	12.40	4.26	6.142
136	trapezoid	27.5	5.197	5	-----	4.43	4.27	6.074
137	trapezoid	18	3.402	0.2	1456	13.20	4.27	6.074
138	trapezoid	19	3.591	0.2	1624	13.19	4.27	6.098

AC Losses of Double Pancake B (single-coil tests) part 2 of 3

Run No.	Charging Pattern	I_{max} (kA)	B_{max} (T)	T_m (S)	AC Loss (kJ)	inlet flow (g/s)	inlet temp. (K)	inlet press. (absolute) (atm.)
139	trapezoid	20	3.780	0.2	1879	13.25	4.26	6.074
140	triangle	1.5	0.284	5	-----	-----	4.36	5.910
141	triangle	1.5	0.284	5	-----	-----	4.36	5.885
142	trapezoid	22	4.158	5	957	12.41	4.36	5.885
143	trapezoid	22	4.158	2	1025	12.41	4.36	5.929
144	trapezoid	22	4.158	1.5	1101	12.45	4.37	6.002
145	trapezoid	22	4.158	0.75	1488	12.53	4.37	6.050
146	trapezoid	22	4.158	0.5	1552	12.48	4.37	6.074
149	trapezoid	15	2.835	0.2	1022	12.45	4.37	6.050
150	2-step trapezoid	22/27	5.103	1/1/1	1580	11.36	4.37	6.074
151	2-step trapezoid	22/30	5.670	1/1/1	1839	12.50	4.37	6.050
155	2-step trapezoid	22/30	5.670	2/3/0.75	1772	12.49	4.39	5.885
157	trapezoid	28	5.292	6	1220	12.17	4.38	6.002
158	trapezoid	28	5.292	5	1190	12.35	4.37	6.050
160	trapezoid	29	5.481	8	1750	11.36	4.38	5.977
162	double trapezoid	12	2.268	0.5	1071	12.48	4.38	5.953
163	double trapezoid	18	3.402	0.5	2000	12.41	4.37	6.002
164	double trapezoid	20	3.780	0.5	2550	12.42	4.37	6.026
166	triple trapezoid	12	2.268	0.5	-----	12.53	4.38	6.026
167	triple trapezoid	18	3.402	0.5	3220	12.50	4.37	6.074
169	triangle	1.5	0.284	5	-----	-----	4.40	5.953
170	triangle	1.5	0.284	5	-----	-----	4.40	6.098
171	quadruple trap.	12	2.268	0.5	-----	-----	4.40	6.118
172	quadruple trap.	12	2.268	0.5	2070	13.10	4.40	6.118
174	quadruple trap.	18	3.402	1.75	2930	12.95	4.40	6.142
175	quadruple trap.	20	3.780	1.75	3540	12.90	4.40	6.166
176	quadruple trap.	22	4.158	1.75	4170	12.95	4.40	6.166
177	round-edge trap.	20	3.780	2.8	1156	13.05	4.40	6.118
178	round-edge trap.	25	4.725	3.5	1578	13.10	4.40	6.166
179	round-edge trap.	28	5.292	3.9	-----	13.13	4.40	6.166
180	round-edge trap.	30	5.670	4.2	2180	13.08	4.40	6.190
183	trapezoid	30.5	5.764	10	1910	12.18	4.40	6.074
184	trapezoid	30.5	5.764	9	1909	12.01	4.40	6.118
185	trapezoid	30.5	5.764	8	1930	11.96	4.40	6.142
187	trapezoid	29.5	5.575	9	1780	12.05	4.41	6.074
188	trapezoid	31	5.859	9	1993	12.00	4.40	6.098
190	round-edge trap.	33	6.237	12	2280	12.58	4.38	5.552
192	round-edge trap.	34	6.426	14	2360	13.16	4.40	5.247
194	round-edge trap.	35	6.615	14	2530	11.92	4.41	5.527
195	2-step trapezoid	20/25	4.725	4/3/1	1204	12.29	4.39	5.673

AC Losses of Double Pancake B (single-coil tests) part 3 of 3

Run No.	Charging Pattern	I_{max} (kA)	B_{max} (T)	T_m (S)	AC Loss (kJ)	inlet flow (g/s)	inlet temp. (K)	inlet press. (absolute) (atm.)
196	2-step trapezoid	20/25	4.725	1.6/3/0.4	1264	12.27	4.39	5.740
197	2-step trapezoid	20/25	4.725	0.8/3/0.2	1520	12.24	4.39	5.764
198	2-step trapezoid	20/25	4.725	0.4/3/0.1	1983	12.39	4.39	5.789
199	triangle	1.5	0.284	5	-----	-----	4.36	2.812
200	triangle	1.5	0.284	5	-----	-----	4.37	2.763
202	trapezoid	22	4.158	1	1421	12.83	4.36	2.763
205	trapezoid	20	3.780	1	1238	12.67	4.35	2.787
206	rippled trapezoid	20	3.780	1	1530	12.64	4.35	2.787
207	rippled trapezoid	20	3.780	1	3910	12.70	4.35	2.787
208	trapezoid	23	4.347	1	1338	12.78	4.37	6.026
210	trapezoid	20	3.780	5	-----	8.30	4.36	6.098
211	trapezoid	20	3.780	1	-----	8.38	4.36	6.098
212	trapezoid	20	3.780	0.5	-----	8.49	4.36	6.098
213	trapezoid	20	3.780	0.3	-----	8.37	4.36	6.074
214	trapezoid	23	4.347	1	-----	8.40	4.37	6.098
215	trapezoid	20	3.780	0.3	-----	10.00	4.36	6.098
216	trapezoid	23	4.347	1	-----	9.88	4.37	6.050
219	2-step trapezoid	22/27	5.103	1/1/1	1672	12.741	4.38	5.929
221	2-step trapezoid	22/30	5.670	1/1/1.6	1965	12.74	4.37	5.910
222	2-step trapezoid	22/30	5.670	1/1/1/6	2020	12.57	4.37	5.977
224	2-step + ripple	22/29	5.481	1/1/1.6	2070	12.27	4.37	5.929
225	2-step + ripple	22/29	5.481	1/1/1.6	2420	11.54	4.37	5.953
227	triangle	1.5	0.284	5	-----	-----	4.71	5.600
228	triangle	1.5	0.284	5	-----	-----	4.71	5.624
229	trapezoid	20	3.780	1	-----	7.56	4.70	5.624
230	trapezoid	23	4.347	1	1395	7.64	4.70	5.648
231	trapezoid	24	4.536	1	1513	7.58	4.70	5.789
233	trapezoid	25	4.725	1.5	1314	7.47	-----	5.837
235	rippled trapezoid	25	4.725	1.5	1887	7.47	4.69	5.789
236	rippled trapezoid	26	4.914	1.5	-----	-----	4.69	5.789
241	trapezoid	30	5.670	11	1997	6.78	4.68	5.740
242	trapezoid	30	5.670	10	-----	-----	4.67	5.837
243	rippled trapezoid	30	5.670	9	3210	7.68	4.67	5.861
244	rippled trapezoid	30	5.670	8	3130	7.67	4.67	5.861
246	trapezoid	20	3.780	5	1414	7.72	6.22	6.002
247	trapezoid	20	3.780	1.5	1630	7.72	6.25	6.050
248	trapezoid	20	3.780	0.75	1475	7.72	6.25	6.190
249	trapezoid	20	3.780	0.3	2495	4.80	6.24	5.910
250	round-edge trap.	30	5.670	6/3/1.9/3/1	-----	-----	4.70	6.215
251	rippled trapezoid	30	5.670	7	3280	12.92	4.69	6.142

AC Losses of Double Pancake B (series-coil tests)

Run No.	Charging Pattern	Imax (kA)	Bmax (T)	Tm (S)	AC Loss (kJ)	inlet flow (g/s)	inlet temp. (K)	inlet press. (absolute) (atm.)
254	triangle	1.5	0.461	5	-----	-----	4.32	6.026
255	triangle	1.5	0.461	5	-----	-----	4.32	6.026
256	triangle	6	1.844	0.75	-----	12.77	4.33	6.002
257	triangle	12	3.688	0.75	-----	12.82	4.32	6.026
258	triangle	18	5.532	0.75	322?	12.84	4.32	5.977
259	triangle	24	7.376	0.75	674?	12.90	4.33	5.977
261	trapezoid	12	3.688	1	-----	12.88	4.34	5.813
262	trapezoid	18	5.532	1	747	12.94	4.33	5.861
265	trapezoid	21	6.454	1	935	13.06	4.34	5.953
267	round-edge trap.	12	3.688	1.7	431	12.08	4.36	5.764
268	round-edge trap.	15	4.610	2.1	-----	12.08	4.36	5.837
269	round-edge trap.	18	5.532	2.5	-----	12.01	4.38	5.552
270	round-edge trap.	20	6.147	2.8	2140?	11.75	4.40	5.503
271	round-edge trap.	22	6.761	3	-----	-----	4.40	-----
272	trapezoid	18	5.532	0.75	877	12.02	4.35	5.977
273	trapezoid	18	5.532	1.5	624	12.05	4.36	5.953
274	trapezoid	18	5.532	5	-----	-----	4.36	5.910
277	rippled trapezoid	22	6.761	1	1189	12.62	4.37	5.861

Appendix D. Listing of coil test runs

Run No.	Date	Time	Purpose	Current Level	Ramp Rate	CM	DM	Comment
1	11/13	15:37	5% Charge	0.350 kA	0.5 kA/min			Ramp, hold, down. Debug instruments.
2		15:56	5%	0.346	500			Ramp, hold, down. Debug instruments.
3		15:56	5%	1.5	500	5		4 min hold. Accidental manual dump. ok
4		16:25	5%	1.5	500			Ramp, hold, 1000 A/min down.
5		16:33	5%	1.5	2	6		Ramp, hold. Manual dump. ok
6		16:53	5%	1.5	2	8	38	Ramp, hold. Manual dump by valve V1 (MC01). ok
7		17:08	5%	1.5	2		39	Ramp, hold. Manual dump. ok
8	11/14	10:50	5% Charge	1.5 kA	2 kA/min		40	System check: 5% charge, manual dump. ok
9		11:15	10%	3	0.5			Ramp, hold 15 min, 500 A/min down.
10		11:36	10%	3	1			Ramp, hold, 2 kA/min down.
11		11:44	10%		5			Ramp. Dump from dbl. pancake C (5/6) balance circuit.
12		13:17	10%	1	2		41	Two-step ramp. Hold at 3 kA for 10 min.
				3	5			Manual dump. ok
13		13:49	30%	9	0.5			Ramp, hold, 1 kA/min down. Voltage spikes.
14		14:24	30%	9	1			Ramp, hold, 2 kA/min down. 400 µV pancake 1?
15		14:52	30%	1	2			Two-step ramp, hold, 5 kA/min down.
				9	5			Hold. ok
16		15:07	30%	1	2			Two-step ramp, hold. Increased mass flow.
				9	5	10	34	Dump from USMC01 upper flow threshold.
17		15:59	30%	1	2			Two-step ramp, hold, manual dump. ok
				9	5	11	35	Hold. ok
18		17:05	70%	1	2			Ramp and hold for five steps.
				9	5			Hold. ok
				15	0.5			Voltage spikes.
				18	0.5			Hold. ok
				21	0.5			Hold. ok
19	11/15	11:18	5% Charge	1.5 kA	0.5 kA/min		36	System check: 5% charge, manual dump. ok
20		11:41	100%	9	5			Ramp and hold in several steps.
				15	2			Hold. ok
				18	1			Hold. ok
				21	0.5			Hold. ok
				24	0.2			Hold. ok

Run No.	Date	Time	Purpose	Current Level	Ramp Rate	CM	DM	Comment
				27	0.2			Hold. ok
				28 ?	0.2			Noise (?) - crossover turn of double pancake A.
				27	0.2 down			Hold. ok
				29.2	0.2			Heating at TC10.
				28.6	0.2 down			Hold. ok
				29.9	0.2	13	37	Dump due to power supply overheat. Coil ok.
21		15:55	100%	< 2	5	14		Immediate dump. USFC01. Broken compensation coil in
								double pancake A. (Go to three point balance method.)
22	11/16	15:01	5% Charge	1.5	0.5	23	42	System check: 5% charge, manual dump. ok
23		15:18	100%	1	2			Ramp and hold in several steps.
				10.6	5			Noise.
				15	5			Hold. ok
				21	2			Hold. ok
				24	1			Hold. ok
				26.2	0.5			Voltage signal.
				27	0.5			Hold. ok
				30	0.2			Hold. ok. Ramp down in steps.
24		17:18	100%	13.3	5			Ramp and hold: no flow in corners of B. Noise (?) 13.3 kA.
				16.5	5			Hold. ok
				21	5			Hold. ok
				24	2			Hold. ok
				27	1			Hold. ok
				30	0.5			Hold. 40 µV on B crossover? Ramp down in steps.
25	11/16	18:14	100% Charge	1 kA	2 kA/min			Ramp and hold: no flow in cable space of B.
				15	5			Hold. ok
				21	2			Hold. ok
				24	1			Hold. ok
				27	0.5			Hold. ok
				30	0.2			Hold. 40 µV on B crossover? Ramp down in steps.
26	11/20	11:02	5%	1.5	0.5	26	43	Check. Quench 1.2 kA. TC10. Heat leak: positive lead.
27		15:24	5%	1.5	0.5	29	44	System check: 5% charge, manual dump. ok
28		15:42	Tcs (33%)	1	2			Current-sharing temperature.

Run No.	Date	Time	Purpose	Current Level	Ramp Rate	CM	DM	Comment
				10	5			Tcs (TC01) = 13.6 K; B = 1.89 T; I = 10 kA.
29		17:53	Tcs (50%)	1	2			Current-sharing temperature. Nonstop. Hold.
				15	5			Tcs (TC01) = 12.5 K; B = 2.83 T; I = 15 kA.
						30		Quench going down: 11.7 kA. (VB-34)
30		20:13	Tcs (67%)	1	2			Current-sharing temperature. Nonstop. Hold.
				20	5			Tcs (TC01) = 11.55 K; B = 3.79 T; I = 20.1 kA.
						31	45	Quench going down: 16.1 kA. (VB-34)
31	11/21	10:16	5%	1.5	0.5	32	46	System check: 5% charge, manual dump. ok
32		10:42	100%	1	2			Intermediate ramp rate test. Nonstop.
				30	5			Hold. ok. 5 kA/min down.
33		11:07	100%	1	2			Intermediate ramp rate test. Nonstop.
				30	10	33		Hold. ok. 10 kA/min down. Dump at ≈ 1kA. Incoloy 908?
34		11:32	100%	1	2			Intermediate ramp rate test. Nonstop.
				30	15			Hold. ok. 15 kA/min down to 2 kA, then 2 kA/min down.
35		11:46	100%	1	2			Intermediate ramp rate test. Nonstop.
				30	20			Hold. ok. 20 kA/min down to 2 kA, then 2 kA/min down.
36		13:16	100%	1	1.25			Intermediate ramp rate test. Nonstop.
				30	25			Hold. ok. 25 kA/min down to 2 kA, then 1.25 kA/min down.
37		13:35	100%	1	1.5			Intermediate ramp rate test. Nonstop.
				30	28			Hold. ok. 28 kA/min down to 2 kA, then 1.5 kA/min down.
38		13:41	100%	1	1.5			Intermediate ramp rate test. Nonstop. Repeat of run 37.
				30	28		47	Hold. ok. 28 kA/min down to 2 kA, then 1.5 kA/min down.
39		15:08	100%	1 kA	1.5 kA/min			Simulated nuclear heating in B. Inlet: 4.5 K, 6.5 atm, 60 g/s
				20	10			Hold. Heater power = 84.2 W.
		15:30		30	10			Hold. Heater power = 82.1 W.
40		16:45	100%	1	2			Simulated nuclear heating in B. Inlet: 4.5 K, 6.5 atm, 60 g/s
				30	10		48	Hold. 100 W, 152 W
							49	208 W
						34	50	Manual dump from 30 kA (second full current dump).
41		17:49	5%	1.5	0.5			System check: 5% charge, manual dump. ok
42	11/22	10:15	5%	1.5	0.5		51	System check: 5% charge, manual dump. ok
43		10:35	Tcs (83%)	1	2			Current-sharing temperature. Nonstop. Hold.

Run No.	Date	Time	Purpose	Current Level	Ramp Rate	CM	DM	Comment
				25	10		52	Tcs (TC01) = 10.5 K; B = 4.74 T; I = 25.1 kA. Ramp down
44		13:16	Tcs (100%)	1	2			Current-sharing temperature. Nonstop. Hold.
				30	10			Tcs (TC01) = 9.3 K; B = 5.66 T; I = 30 kA. Ramp down.
45		15:25	Ic (11 K)	17	2			Critical current measurement. Two ramp rates.
				19.02	0.2			Ic = 19.02 kA; T = 11.75 K; B = 3.59 T
46		15:59	Ic (11 K)	22.94	0.5		53	Critical current measurement. Fixed ramp rate.
								Ic = 22.94 kA; T = 10.96 K; B = 4.33 T
47	12/4	14:01	5% Series	1.5 kA	0.5 kA/min			U1+U2+US System check: 5% charge, manual dump. ok
48		14:22	5% Series	1.5	1			Check. Manual dump. ok. Broke fiber optic cable.
49-1		15:05	5% Series	1.5	1	55	85	Check under current setting on quench detector.
49-2		15:11		1.5	2			
49-3		15:17		1.5	5			
50		15:23	16.7% Series	5	1			Hold. 2 kA/min down.
51		15:35	16.7% Series	5	5			Hold. 5 kA/min down.
52		15:42	30% Series	5	5			Nonstop
				10	1			Hold
				3	5			Nonstop
				10	2			Hold
				3	5			Nonstop
				10	5			Hold
				12	1			Hold
				14	0.5	57	86	Quench of U1 at 13.65 kA
53		16:32	Charge	10	5			Nonstop
				13	1			Hold
				8	2			Nonstop
				13	2			Nonstop
				8	5			Nonstop
				13	5			Hold
				8	5			Nonstop
				13	5			Hold 30 min
				15	50 A/min			Hold
				19	50 A/min	59	87	Joint quench of US-DPC at 17.25 kA; insufficient LHe flow

Run No.	Date	Time	Purpose	Current Level	Ramp Rate	CM	DM	Comment
54		19:53	5% Check	1.5	1			U1+U2+US System check: 5% charge. ok
55	12/5	8:35	5% Check	1.5 kA	0.5 kA/min	62		U1+U2+US System check: 5% charge. ok
56		9:30	Charge	10	5 kA/min			Stop at 8.3 kA. Ramp down. US-DPC joint heating.
57		9:55	Charge	5	1			Hold
				13	1	64	88	Quench of U1 at 12.8 kA
58		10:24	Charge	12	1			Hold
				8	2			Nonstop
				12	2			Nonstop
				8	5			Nonstop
				12	5			Nonstop
				8	5			Nonstop
				12	5			30 min hold
		11:18		15	100 A/min			Hold
				12	200			Nonstop
				15	200			Nonstop
				12	500			Nonstop
				15	500			Nonstop
				12	500			Nonstop
				15	500			30 min hold
		13:11		17	100			Hold
				15	200			Nonstop
				17	200			Nonstop
				15	500			Down, hold. Temperature increase B/C lap joint.
				17	500			Nonstop
				15	500			Nonstop
				17	500			30 min hold
		14:47		19	50			Hold at 18.4 kA for U1 balance. Stop at 19.09 kA.
				17	100			Nonstop
				19	100			Nonstop
				17	200			Hold ?
				19	200			Nonstop
				17	500			Nonstop

Run No.	Date	Time	Purpose	Current Level	Ramp Rate	CM	DM	Comment
				19	500			30 min hold
		17:11		21	50			Hold at 21.1 kA.
				19	100			Nonstop
				21	100			Nonstop
				19	200			Nonstop
				21	200			Nonstop
				19	500			Nonstop
				21	500			30 min hold
		19:31		23	50			Hold at 21.8 kA. U2 flowmeter U2MC03
				23	50			Hold at 23.1 kA.
				21	100			Nonstop
				23	100			Nonstop
				21	200			Nonstop
				23	200			Nonstop
				21	500			Nonstop
				23	500			30 min hold
		21:56		25	50			Hold 23.9 kA
				25	50			Hold 24.8 kA
				25	50			Hold
				23	100			Nonstop
				25	100			Nonstop
				23	200			Nonstop
				25	200			Nonstop
				23	500			Nonstop
				25	500			30 min hold
	12/6	0:22		27	50	66	89	Quench of U1 at 25.89 kA. U1VB-AB
59	12/6	0:56	5% Check	1.5 kA	1 kA/min			Hold, down. ok
60	12/7	10:04	5% Check	1.5	500 A/min		90	Hold. Manual dump. ok
61		10:15	17%	5	1 kA/min			Hold. 2 kA/min down. Quench detector balance calibration.
62		10:26	23%	7	2			Hold. 5 kA/min down. Quench detector balance calibration.
63		10:32	33%	10	5			Hold. 10 kA/min down. Quench detector balance calibration.
64		10:40	66%	20	10			Hold. 20 kA/min down. Quench detector balance calibration.

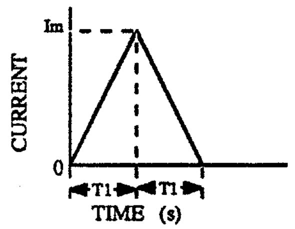
Run No.	Date	Time	Purpose	Current Level	Ramp Rate	CM	DM	Comment
65		10:49	100%	30	20			Hold. 30 kA/min down. Quench detector balance calibration.
66		11:03	100%	30	30			Hold. 30 kA/min down. Quench detector balance calibration.
67		11:15	100%	30	30			Hold. 30 kA/min down. Quench detector balance calibration.
68		11:25	100%	30	30			Hold. 15 kA/min down. Incoloy 908 magnetization signal.
69		11:34	100%	30	15			Hold. 30 kA/min down. Incoloy 908 magnetization signal.
70		11:47	53%	16	15			Triangular wave. I908 magnetization signal measurement.
71		11:54	53%	15	15			Hold. 15 kA/min down. Incoloy 908 magnetization signal.
72		15:41	Ic at 10 K	27.2	1		91	Ic = 26.65 kA at 10μV/m and T = 10.17 K.
73		16:30	Tcs at 5 kA	5	5	68		Tcs = 14.8 K at 5 kA.

Run number 74 DM Shot number ______ Date 12/10/90 Time 11:32

Connection Single coil
Mode AC
Description Single triangle
Total inlet flow ______ g/s
Inlet pressure 5.929 atm
Inlet temperature X K

Bm 0.284 T
Tm 5 s
Bm/Tm 0.057 T/s
1/Tm 0.200 1/s
Im 1.5 kA
Flat top ______ s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s
Im = 1.5 kA
Tm = T1

Quench ? No
Quench time ______ s

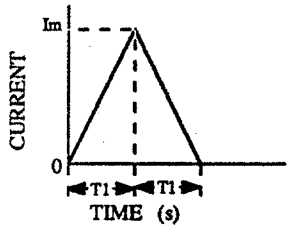
PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X	———	X	X			X		
2		———		X			X		
3 cable	X	X		X			X		
3 corner		X		X			X		
4 corner		X		X			X		
4 cable		X		X			X		
5	X	———	X	X			X		
6		———		X			X		

Run number 75 DM Shot number 92 Date 12/10/90 Time 11:44

Connection Single coil
Mode AC
Description Single triangle
Total inlet flow ______ g/s
Inlet pressure 5.861 atm
Inlet temperature 4.752 K

Bm 0.284 T
Tm 5 s
Bm/Tm 0.057 T/s
1/Tm 0.200 1/s
Im 1.5 kA
Flat top ______ s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s
Im = 1.5 kA
Tm = T1

Quench ? No
Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X	———	4.752				X		
2		———		4.715	4.75	0.04	X		
3 cable	X	X		4.805	4.83	0.03	X		
3 corner		X		4.626	4.66	0.03	X		
4 corner		X		4.713	4.75	0.03	X		
4 cable		X		4.753	4.78	0.03	X		
5	X	———	4.584	4.629	4.67	0.04	X		
6		———		6.513			X		

Run number 76 DM Shot number ____ Date ____ Time 13:25

Connection Single coil
Mode AC
Description Miss shot

Total inlet flow ____ g/s
Inlet pressure ____ atm
Inlet temperature 4.745 K

Bm ____ T
Tm ____ s
Bm/Tm ____ T/s
1/Tm ____ 1/s
Im ____ kA
Flat top ____ s
Im/Tm ____ kA/s

Waveform

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X	—	4.745	X					
2		—		X			X		
3 cable	X	X		X			X		
3 corner		X		X			X		
4 corner		X		X			X		
4 cable		X		X			X		
5	X	—	4.571	X			X		
6		—		X					

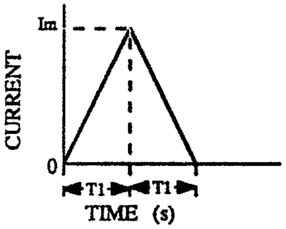
Run number 77 DM Shot number 116 Date 12/10/90 Time 13:43

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow X g/s
Inlet pressure 5.977 atm
Inlet temperature 4.735 K

Bm 0.284 T
Tm 5 s
Bm/Tm 0.057 T/s
1/Tm 0.200 1/s
Im 1.5 kA
Flat top ____ s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s
Im = 1.5 kA

Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X	—	4.735	X					
2		—		4.709	4.75	0.05	X		
3 cable	X	X		4.792	4.83	0.04	X		
3 corner		X		4.614	4.66	0.04	X		
4 corner		X		4.707	4.74	0.04	X		
4 cable		X		4.742	4.78	0.04	X		
5	X	—	4.566	4.616	4.67	0.05	X		
6		—		5.078	5.13	0.06			

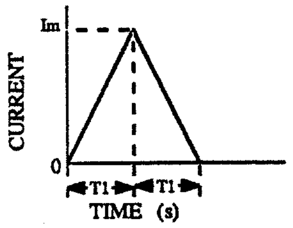
Run number 78 DM Shot number 117 Date 12/10/90 Time 14:15

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow X g/s
Inlet pressure 6.050 atm
Inlet temperature 4.745 K

Bm 0.284 T
Tm .5 s
Bm/Tm 0.568 T/s
1/Tm 2.000 1/s
Im 1.5 kA
Flat top s
Im/Tm 3.00 kA/s

Waveform



T1 = 0.5 s
Im = 1.5 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]
	INLET	OUTLET	INLET	OUTLET			
				INITIAL	PEAK	ΔT	
1	X		4.745	X			
2				4.709	4.73	0.02	X
3 cable	X	X		4.8	4.81	0.01	X
3 corner		X		4.621	4.64	0.01	X
4 corner		X		4.708	4.72	0.01	X
4 cable		X		4.748	4.76	0.01	X
5	X		4.573	4.622	4.64	0.02	X
6				5.084	5.10	0.02	

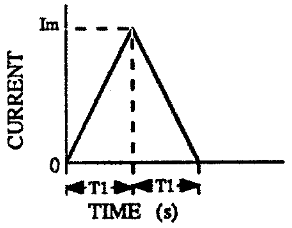
Run number 79 DM Shot number X Date 12/10/90 Time 14:32

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow X g/s
Inlet pressure 6.050 atm
Inlet temperature 4.745 K

Bm 0.284 T
Tm .5 s
Bm/Tm 0.568 T/s
1/Tm 2.000 1/s
Im 1.5 kA
Flat top s
Im/Tm 3.00 kA/s

Waveform



T1 = 0.5 s
Im = 1.5 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]
	INLET	OUTLET	INLET	OUTLET			
				INITIAL	PEAK	ΔT	
1	X		4.745	X			
2				X			X
3 cable	X	X		X			X
3 corner		X		X			X
4 corner		X		X			X
4 cable		X		X			X
5	X		4.573	X			X
6				X			

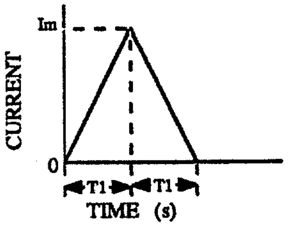
Run number 80 DM Shot number 118 Date 12/10/90 Time 14:43

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 43.3 g/s
Inlet pressure 6.098 atm
Inlet temperature 4.737 K

Bm 1.134 T
Im 6 kA
Tm .5 s
Flat top s
Bm/Tm 2.268 T/s
Im/Tm 12.00 kA/s
1/Tm 2.000 1/s

Waveform



T1 = 0.5 s
Im = 1.5 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.47	—	4.737	X					
2		—		4.704	4.78	0.08	218.9		763.87
3 cable	12.36	1.932		4.795	4.86	0.06	49.86	111.14	
3 corner		2.705		4.616	4.68	0.07	61.28		
4 corner		3.296		4.703	4.78	0.07	84.21	135.73	
4 cable		2.107		4.744	4.80	0.06	51.52		
5	19.47	—	4.566	4.618	4.69	0.08	298.1		
6		—		5.077	5.15	0.07			

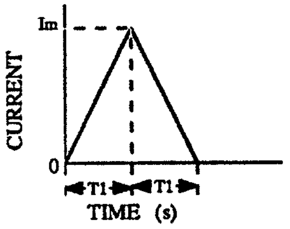
Run number 81 DM Shot number 119 Date 12/10/90 Time 14:54

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 43.49 g/s
Inlet pressure 6.118 atm
Inlet temperature 4.737 K

Bm 1.134 T
Im 6 kA
Tm .5 s
Flat top s
Bm/Tm 2.268 T/s
Im/Tm 12.00 kA/s
1/Tm 2.000 1/s

Waveform



T1 = 0.5 s
Im = 6 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.55	—	4.737	X					
2		—		4.706	4.78	0.07	211		711.4
3 cable	12.37	1.925		4.805	4.85	0.05	39.5	100.8	
3 corner		2.71		4.616	4.68	0.06	61.3		
4 corner		3.31		4.703	4.77	0.07	84.1	133.6	
4 cable		2.17		4.749	4.80	0.05	49.5		
5	19.57	—	4.567	4.623	4.69	0.07	266		
6		—		5.091	5.15	0.06			

Run number 82 DM Shot number 120 Date 12/10/90 Time 15:35

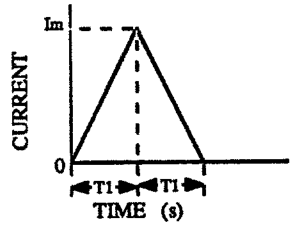
Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 43.31 g/s
Inlet pressure 6.142 atm
Inlet temperature 4.747 K

Bm 2.268 T
Tm .5 s
Bm/Tm 4.536 T/s
1/Tm 2.000 1/s

Im 12 kA
Flat top s
Im/Tm 24.00 kA/s

Waveform



T1 = 0.5 s
Im = 12 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.5	———	4.747	X					
2		———		4.709	4.85	0.14	441		1615.2
3 cable	12.34	1.94		4.8	4.92	0.12	109.6	246.2	
3 corner		2.71		4.62	4.75	0.13	136.6		
4 corner		3.31		4.708	4.85	0.14	182.4	302	
4 cable		2.17		4.747	4.87	0.12	119.6		
5	19.47	———	4.573	4.624	4.76	0.13	626		
6		———		5.085	5.22	0.13			

Run number 83 DM Shot number 121 Date 12/10/90 Time 15:46

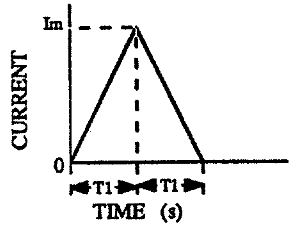
Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 43.3 g/s
Inlet pressure 6.142 atm
Inlet temperature 4.745 K

Bm 3.402 T
Tm .5 s
Bm/Tm 6.804 T/s
1/Tm 2.000 1/s

Im 18 kA
Flat top s
Im/Tm 36.00 kA/s

Waveform



T1 = 0.5 s
Im = 18 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.48	———	4.745	X					
2		———		4.709	4.95	0.24	692.2		2572.5
3 cable	12.36	1.939		4.8	5.00	0.20	183.4	405.6	
3 corner		2.732		4.621	4.83	0.21	222.2		
4 corner		3.312		4.709	4.94	0.23	293.6	491	
4 cable		2.172		4.749	4.94	0.19	197.4		
5	19.46	———	4.574	4.624	4.86	0.23	983.7		
6		———		5.086	5.27	0.18			

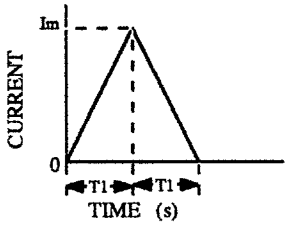
Run number 84 DM Shot number 126 Date 12/10/90 Time 15:56

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 43.32 g/s
Inlet pressure 6.074 atm
Inlet temperature 4.745 K

Bm 3.402 T
Tm .5 s
Bm/Tm 6.804 T/s
1/Tm 2.000 1/s
Im 18 kA
Flat top s
Im/Tm 36.00 kA/s

Waveform



T1 = 0.5 s
Im = 18 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.49	—	4.745	X					
2		—		4.709	4.95	0.24	694.6		1382.6
3 cable	12.34	1.943		4.801	5.00	0.19	181.8	399.2	
3 corner		2.728		4.62	4.83	0.21	217.4		
4 corner		3.313		4.709	4.94	0.23	288.8	288.8	
4 cable		2.172		X					
5	19.49	—	4.574	4.626		-4.63			
6		—		5.086		-5.09			

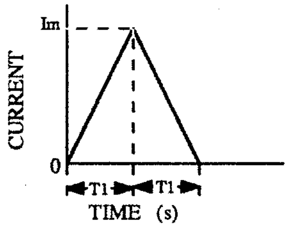
Run number 85 DM Shot number 127 Date 12/10/90 Time 16:06

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 43.59 g/s
Inlet pressure 6.074 atm
Inlet temperature 4.741 K

Bm 4.536 T
Tm .5 s
Bm/Tm 9.072 T/s
1/Tm 2.000 1/s
Im 24 kA
Flat top s
Im/Tm 48.00 kA/s

Waveform



T1 = 0.5 s
Im = 24 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.62	—	4.741	X					
2		—		4.706	5.07	0.36	1064		4000.5
3 cable	12.42	1.949		4.798	5.10	0.30	300.9	637.4	
3 corner		2.748		4.618	4.94	0.32	336.5		
4 corner		3.322		4.706	5.05	0.34	444.6	751.1	
4 cable		2.179		4.746	5.04	0.29	306.5		
5	19.55	—	4.571	4.621	4.97	0.35	1548		
6		—		5.08	5.35	0.27			

Run number 86 DM Shot number 122 Date 12/10/90 Time 16:19

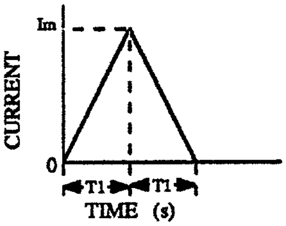
Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 43.3 g/s
Inlet pressure 6.118 atm
Inlet temperature 4.739 K

Bm 4.536 T
Tm .5 s
Bm/Tm 9.072 T/s
1/Tm 2.000 1/s

Im 24 kA
Flat top s
Im/Tm 48.00 kA/s

Waveform



T1 = 0.5 s
Im = 24 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.51	—	4.739	X					
2		—		4.708	5.07	0.36	1073		4035
3 cable	12.37	1.919		4.8	5.10	0.30	296	629	
3 corner		2.72		4.617	4.94	0.32	333		
4 corner		3.3		4.706	5.05	0.34	439	759	
4 cable		2.16		4.747	5.04	0.29	320		
5	19.42	—	4.57	4.62	4.97	0.35	1574		
6		—		5.086	5.35	0.27			

Run number 87 DM Shot number 123 Date 12/10/90 Time 16:29

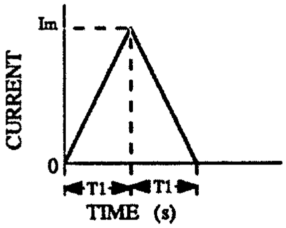
Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 43.49 g/s
Inlet pressure 6.098 atm
Inlet temperature 4.745 K

Bm 5.103 T
Tm .5 s
Bm/Tm 10.206 T/s
1/Tm 2.000 1/s

Im 27 kA
Flat top 0 s
Im/Tm 54.00 kA/s

Waveform



T1 = 0.5 s
Im = 27 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.58	—	4.745	X					
2		—		4.705	5.15	0.45	1360		5180
3 cable	12.44	1.987		4.803	5.18	0.38	437	851	
3 corner		2.76		4.623	5.02	0.39	414		
4 corner		3.34		4.705	5.14	0.43	539	982	
4 cable		2.18		4.75	5.11	0.36	443		
5	19.47	—	4.574	4.623	5.05	0.43	1987		
6		—		5.086	5.41	0.32			

Run number 88 DM Shot number 124 Date 12/10/90 Time 16:39

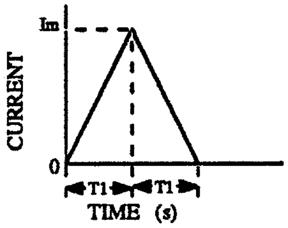
Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 45.79 g/s
Inlet pressure 6.118 atm
Inlet temperature 4.745 K

Bm 5.670 T
Tm .5 s
Bm/Tm 11.340 T/s
1/Tm 2.000 1/s

Im 30 kA
Flat top s
Im/Tm 60.00 kA/s

Waveform



T1 = 0.5 s
Im = 30 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.47		4.745	X					8851.7
2				4.712	5.29	0.57	1853		
3 cable	13.94	2		4.808	5.65	0.84	881.9	1650.9	
3 corner		2.575		4.622	5.50	0.88	769		
4 corner		3.148		4.71	5.74	1.03	1074	2023.8	
4 cable		2.164		4.742	5.59	0.85	949.8		
5	20.38		4.573	4.626	5.36	0.73	3324		
6				5.089	5.60	0.51			

Run number 89 DM Shot number 125 Date 12/10/90 Time 16:55

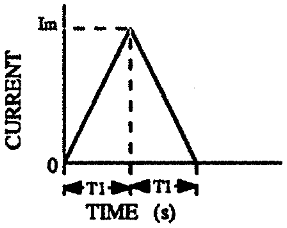
Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 43.65 g/s
Inlet pressure 6.074 atm
Inlet temperature 4.743 K

Bm 5.387 T
Tm .5 s
Bm/Tm 10.774 T/s
1/Tm 2.000 1/s

Im 28.5 kA
Flat top s
Im/Tm 57.00 kA/s

Waveform



T1 = 0.5 s
Im = 28.5 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.4		4.743	X					6540
2				4.709	5.20	0.49	1579		
3 cable	12.32	2.03		4.806	5.23	0.42	577	1048	
3 corner		2.75		4.62	5.07	0.45	471		
4 corner		3.33		4.708	5.21	0.50	630	1196	
4 cable		2.15		4.746	5.17	0.42	566		
5	19.93		4.573	4.624	5.23	0.60	2717		
6				5.086	5.51	0.42			

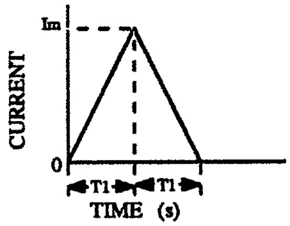
Run number 90 DM Shot number 204 Date 12/11/90 Time 10:04

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow X g/s
Inlet pressure 6.239 atm
Inlet temperature 4.735 K

Bm 0.284 T
Tm 5 s
Bm/Tm 0.057 T/s
1/Tm 0.200 1/s
Im 1.5 kA
Flat top s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s
Im = 1.5 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X		4.735	X					
2				4.706	4.76	0.05	X		
3 cable	X	X		4.808	4.84	0.03	X		
3 corner		X		4.616	4.66	0.04	X		
4 corner		X		4.706	4.75	0.04	X		
4 cable		X		4.748	4.78	0.03	X		
5	X		4.566	4.62	4.67	0.05	X		
6				5.098	5.15	0.05			

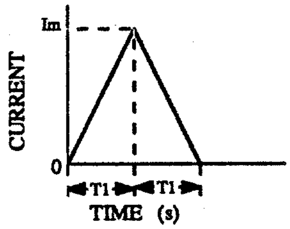
Run number 91 DM Shot number 205 Date 12/11/90 Time 10:19

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow X g/s
Inlet pressure 6.287 atm
Inlet temperature 4.735 K

Bm 0.284 T
Tm 5 s
Bm/Tm 0.057 T/s
1/Tm 0.200 1/s
Im 1.5 kA
Flat top s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s
Im = 1.5 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X		4.735	X					
2				4.707	4.74	0.03	X		
3 cable	X	X		4.809	4.83	0.02	X		
3 corner		X		4.618	4.64	0.02	X		
4 corner		X		4.707	4.73	0.03	X		
4 cable		X		4.75	4.77	0.02	X		
5	X		4.566	4.621	4.65	0.03	X		
6				5.097	5.13	0.04			

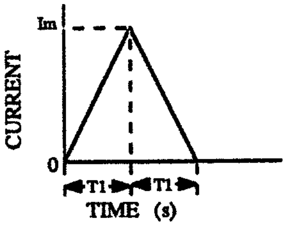
Run number 92 DM Shot number 206 Date 12/11/90 Time 10:43

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 44.2 g/s
Inlet pressure 6.331 atm
Inlet temperature 4.741 K

Bm 5.481 T
Tm .5 s
Bm/Tm 10.962 T/s
1/Tm 2.000 1/s
Im 29 kA
Flat top s
Im/Tm 58.00 kA/s

Waveform



T1 = 0.5 s
Im = 29 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.39	———	4.741	4.694	5.10	0.40			
2		———		4.709	5.22	0.51	1634		6351
3 cable	12.61	1.956		4.812	5.25	0.44	583	1059	
3 corner		2.72		4.621	5.09	0.47	476		
4 corner		3.37		4.71	5.22	0.51	637	1228	
4 cable		2.15		4.751	5.18	0.43	591		
5	20.2	———	4.571	4.623	5.12	0.50	2430		
6		———		5.098	5.47	0.37			

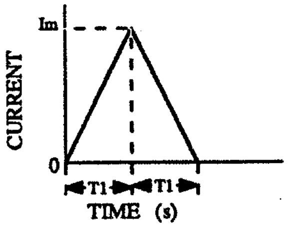
Run number 93 DM Shot number 207 Date 12/11/90 Time 11:12

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 44.67 g/s
Inlet pressure 6.287 atm
Inlet temperature 4.737 K

Bm 5.481 T
Tm .5 s
Bm/Tm 10.962 T/s
1/Tm 2.000 1/s
Im 29 kA
Flat top s
Im/Tm 58.00 kA/s

Waveform



T1 = 0.5 s
Im = 29 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.46	———	4.737	4.685	5.08	0.40			
2		———		4.708	5.21	0.50	1639		6782.7
3 cable	12.66	2.951		4.807	5.24	0.43	874.6	1341.9	
3 corner		2.698		4.617	5.08	0.46	467.3		
4 corner		3.35		4.706	5.21	0.50	632.3	1207.8	
4 cable		2.119		4.747	5.18	0.43	575.5		
5	20.55	———	4.566	4.619	5.16	0.54	2594		
6		———		5.091	5.52	0.43			

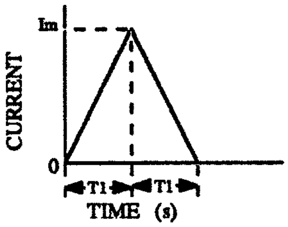
Run number 94 DM Shot number 208 Date 12/11/90 Time 11:33

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 41.685 g/s
Inlet pressure 5.452 atm
Inlet temperature 4.737 K

Bm 5.670 T
Im 30 kA
Tm 1 s
Flat top s
Bm/Tm 5.670 T/s
Im/Tm 30.00 kA/s
1/Tm 1.000 1/s

Waveform



T1 = 1 s
Im = 30 kA
Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
Quench sequence ?
VB#34,56

Quench time 0.9 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	13.304	———	4.737	4.691	5.24	0.55			
2		———		4.704	5.52	0.82	3468		16255.8
3 cable	13.595	1.993		4.805	5.78	0.98	929.8	1972.8	
3 corner		2.698		4.618	5.63	1.01	1043		
4 corner		3.207		4.708	6.35	1.64	1954	3480	
4 cable		2.526		4.752	6.10	1.35	1526		
5	14.786	———	4.564	4.618	6.82	2.20	7335		
6		———		5.092	6.38	1.28			

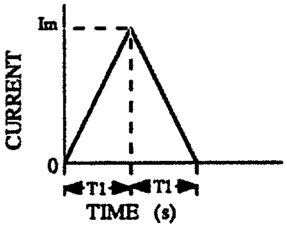
Run number 95 DM Shot number 209 Date 12/11/90 Time 11:45

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 40.49 g/s
Inlet pressure 5.452 atm
Inlet temperature 4.741 K

Bm 5.481 T
Im 29 kA
Tm 1 s
Flat top s
Bm/Tm 5.481 T/s
Im/Tm 29.00 kA/s
1/Tm 1.000 1/s

Waveform



T1 = 1 s
Im = 29 kA
Tm = T1

Quench ? Yes- Coil C crossover turn and other part.

Quench detection sequence
Quench sequence ?
VB#34,56

Quench time 0.93 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	12.408	———	4.741	4.695	5.22	0.52			
2		———		4.708	5.49	0.78	3102		15038.7
3 cable	13.685	2.007		4.807	5.75	0.94	902.7	1930.7	
3 corner		2.735		4.621	5.61	0.99	1028		
4 corner		3.226		4.708	6.33	1.62	1902	3372	
4 cable		2.529		4.752	6.08	1.32	1470		
5	14.397	———	4.568	4.623	6.75	2.13	6634		
6		———		5.097	6.38	1.28			

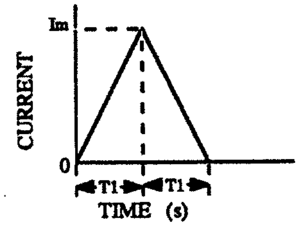
Run number 96 DM Shot number 210 Date 12/11/90 Time 13:20

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 43.53 g/s
Inlet pressure 6.239 atm
Inlet temperature 4.733 K

Bm 5.481 T
Tm .5 s
Bm/Tm 10.962 T/s
1/Tm 2.000 1/s
Im 29 kA
Flat top s
Im/Tm 58.00 kA/s

Waveform



T1 = 0.5 s
Im = 29 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.39	———	4.733	4.677	5.08	0.40			
2		———		4.692	5.20	0.51	1662		6791
3 cable	12.64	2.01		4.8	5.25	0.45	595	1075	
3 corner		2.73		4.629	5.09	0.46	480		
4 corner		3.36		4.703	5.23	0.53	647	1234	
4 cable		2.15		4.746	5.19	0.44	587		
5	20.5	———	4.561	4.616	5.25	0.63	2820		
6		———		5.09	5.52	0.43			

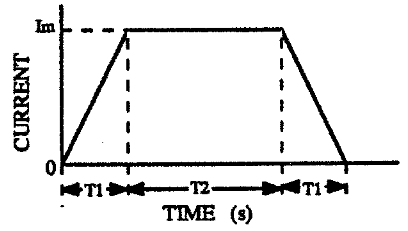
Run number 97 DM Shot number 211 Date 12/11/90 Time 13:32

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.88 g/s
Inlet pressure 6.287 atm
Inlet temperature 4.733 K

Bm 2.268 T
Tm .5 s
Bm/Tm 4.536 T/s
1/Tm 2.000 1/s
Im 12 kA
Flat top 3 s
Im/Tm 24.00 kA/s

Waveform



T1 = 0.5 s
T2 = 3 s
Im = 29 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.28	———	4.733	4.675	4.82	0.15			
2		———		4.689	4.86	0.17	480		1730.2
3 cable	12.6	1.86		4.801	4.94	0.13	112.9	254.9	
3 corner		2.67		4.617	4.76	0.15	142		
4 corner		3.34		4.704	4.86	0.16	189	311.3	
4 cable		2.13		4.748	4.88	0.13	122.3		
5	20	———	4.561	4.618	4.78	0.16	684		
6		———		5.095	5.23	0.14			

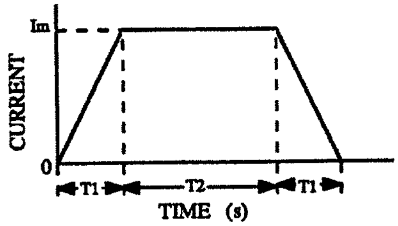
Run number 98 DM Shot number 212 Date 12/11/90 Time 13:45

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.85 g/s
Inlet pressure 6.355 atm
Inlet temperature 4.735 K

Bm	3.402 T	Im	18 kA
Tm	.5 s	Flat top	3 s
Bm/Tm	6.804 T/s	Im/Tm	36.00 kA/s
1/Tm	2.000 1/s		

Waveform



T1 = 0.5 s
T2 = 3 s

Im = 18 kA

Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.24	————	4.735	4.655	4.90	0.25			
2		————		4.691	4.97	0.28	795		2887
3 cable	12.61	1.895		4.802	5.03	0.22	205	449	
3 corner		2.73		4.619	4.86	0.24	244		
4 corner		3.36		4.707	4.96	0.25	320	534	
4 cable		2.11		4.75	4.97	0.22	214		
5	20	————	4.566	4.621	4.88	0.26	1109		
6		————		5.094	5.30	0.21			

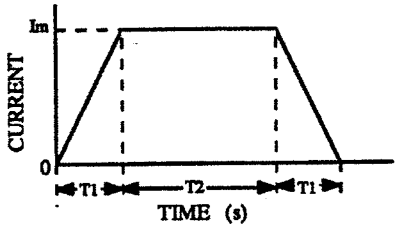
Run number 99 DM Shot number 213 Date 12/11/90 Time 13:57

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.555 g/s
Inlet pressure 5.47 atm
Inlet temperature 4.737 K

Bm	4.536 T	Im	24 kA
Tm	.5 s	Flat top	3 s
Bm/Tm	9.072 T/s	Im/Tm	48.00 kA/s
1/Tm	2.000 1/s		

Waveform



T1 = 0.5 s
T2 = 3 s

Im = 24 kA

Tm = T1

Quench ? Yes- Quench information ?

Quench detection sequence
Quench sequence ?
VB34,56

Quench time -- s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.674	————	4.737	4.679	5.13	0.45			
2		————		4.691	5.28	0.59	1685		60588.6
3 cable	12.764	2.242		4.803	5.30	0.50	659.3	1214.8	
3 corner		2.796		4.62	5.14	0.52	555.5		
4 corner		3.229		4.709	5.27	0.56	677.4	1411.8	
4 cable		2.391		4.75	5.24	0.49	734.4		
5	20.117	————	4.566	4.612			56277		
6		————		5.094	5.50	0.40			

Run number 100 DM Shot number 222 Date 12/11/90 Time 14:17

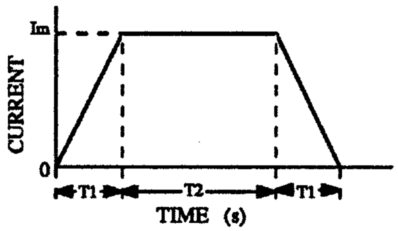
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.62 g/s
Inlet pressure 6.239 atm
Inlet temperature 4.735 K

Bm 3.969 T
Tm .5 s
Bm/Tm 7.938 T/s
1/Tm 2.000 1/s

Im 21 kA
Flat top 3 s
Im/Tm 42.00 kA/s

Waveform



T1 = 0.5 s
T2 = 3 s

Im = 21 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.77	———	4.735	4.666	4.95	0.28			
2		———		4.685	5.04	0.35	1026		3785
3 cable	12.65	2		4.801	5.09	0.28	307	622	
3 corner		2.75		4.617	4.92	0.30	315		
4 corner		3.39		4.703	5.03	0.33	412	702	
4 cable		2.19		4.751	5.02	0.27	290		
5	20.2	———	4.563	4.619	4.94	0.32	1435		
6		———		5.093	5.35	0.26			

Run number 101 DM Shot number 223 Date 12/11/90 Time 14:25

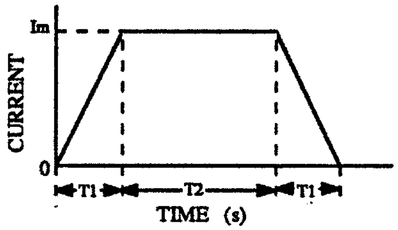
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.25 g/s
Inlet pressure 6.331 atm
Inlet temperature 4.73 K

Bm 2.835 T
Tm 5 s
Bm/Tm 0.567 T/s
1/Tm 0.200 1/s

Im 15 kA
Flat top 3 s
Im/Tm 3.00 kA/s

Waveform



T1 = 5 s
T2 = 3 s

Im = 15 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.7	———	4.73	4.67	4.81	0.14			
2		———		4.682	4.85	0.17	476		1786.7
3 cable	12.55	1.888		4.797	4.94	0.14	119.1	270.8	
3 corner		2.68		4.613	4.76	0.15	151.7		
4 corner		3.31		4.702	4.86	0.16	199.6	326.9	
4 cable		2.14		4.747	4.88	0.13	127.3		
5	20	———	4.558	4.615	4.78	0.17	713		
6		———		5.094	5.24	0.14			

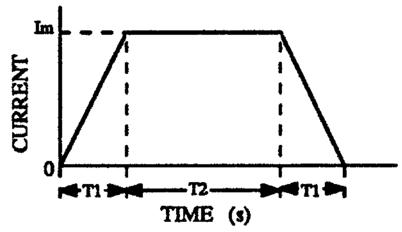
Run number 102 DM Shot number 214 Date 12/11/90 Time 14:37

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.25 g/s
Inlet pressure 6.355 atm
Inlet temperature 4.73 K

Bm 2.835 T
Tm 2 s
Bm/Tm 1.418 T/s
1/Tm 0.500 1/s
Im 15 kA
Flat top s
Im/Tm 7.50 kA/s

Waveform



T1 = 2 s
T2 = 3 s

Im = 15 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.69	———	4.73	4.672	4.82	0.15			
2		———		4.681	4.86	0.18	491		1837.7
3 cable	12.56	1.885		4.798	4.94	0.14	121.6	278.5	
3 corner		2.7		4.614	4.77	0.15	156.9		
4 corner		3.36		4.703	4.87	0.17	209	339.2	
4 cable		2.12		4.748	4.89	0.14	130.2		
5	20	———	4.56	4.616	4.79	0.17	729		
6		———		5.095	5.24	0.15			

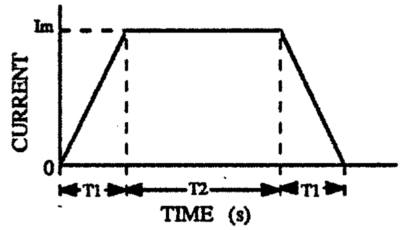
Run number 103 DM Shot number 215 Date 12/11/90 Time 14:50

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.54 g/s
Inlet pressure 6.355 atm
Inlet temperature 4.733 K

Bm 2.835 T
Tm 1.5 s
Bm/Tm 1.890 T/s
1/Tm 0.667 1/s
Im 15 kA
Flat top 3 s
Im/Tm 10.00 kA/s

Waveform



T1 = 1.5 s
T2 = 3 s

Im = 15 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.79	———	4.733	4.669	4.52	[illegible]			
2		———		4.681	4.86	0.18	516		1903.2
3 cable	12.65	1.905		4.798	4.95	0.15	126.9	289.2	
3 corner		2.71		4.615	4.76	0.15	162.3		
4 corner		3.37		4.703	4.87	0.17	213	347	
4 cable		2.14		4.747	4.89	0.14	134		
5	20.1	———	4.56	4.616	4.79	0.18	751		
6		———		5.092	5.24	0.15			

Run number 104 DM Shot number 216 Date 12/11/90 Time 15:35

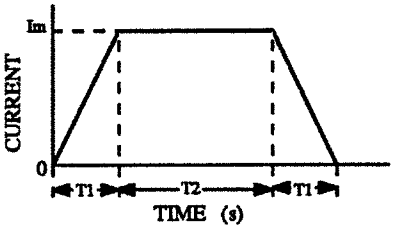
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.31 g/s
Inlet pressure 6.355 atm
Inlet temperature 4.73 K

Bm 2.835 T
Tm 1 s
Bm/Tm 2.835 T/s
1/Tm 1.000 1/s

Im 15 kA
Flat top 3 s
Im/Tm 15.00 kA/s

Waveform



T1 = 1 s
T2 = 3 s
Im = 15 kA

Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.73	—	4.73	4.665	4.83	0.16			
2		—		4.678	4.87	0.20	543		1994.5
3 cable	12.58	1.9		4.796	4.95	0.16	133.8	302.8	
3 corner		2.7		4.61	4.78	0.17	169		
4 corner		3.37		4.701	4.88	0.18	225.8	367.7	
4 cable		2.13		4.744	4.90	0.15	141.9		
5	20	—	4.557	4.613	4.80	0.19	781		
6		—		5.09	5.25	0.16			

Run number 105 DM Shot number 217 Date 12/11/90 Time 15:47

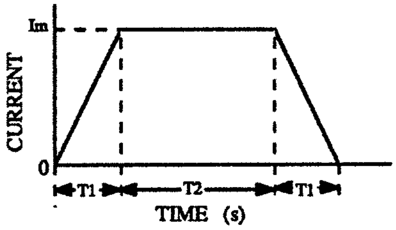
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.73 g/s
Inlet pressure 6.403 atm
Inlet temperature 4.73 K

Bm 2.835 T
Tm .75 s
Bm/Tm 3.780 T/s
1/Tm 1.333 1/s

Im 15 kA
Flat top 3 s
Im/Tm 20.00 kA/s

Waveform



T1 = 0.75 s
T2 = 3 s
Im = 15 kA

Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.86	—	4.73	4.668	4.84	0.17			
2		—		4.68	4.89	0.21	578		2101.1
3 cable	12.67	1.878		4.798	4.96	0.16	139.9	316.9	
3 corner		2.69		4.612	4.79	0.18	177		
4 corner		3.35		4.702	4.89	0.19	234	384.2	
4 cable		2.13		4.745	4.91	0.16	150.2		
5	20.2	—	4.558	4.614	4.81	0.19	822		
6		—		5.09	5.25	0.16			

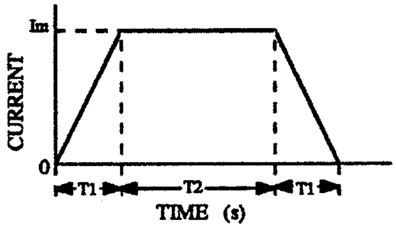
Run number 106 DM Shot number 218 Date 12/11/90 Time 15:58

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.68 g/s
Inlet pressure 6.287 atm
Inlet temperature 4.728 K

Bm 2.835 T
Tm .5 s
Bm/Tm 5.670 T/s
1/Tm 2.000 1/s
Im 15 kA
Flat top 3 s
Im/Tm 30.00 kA/s

Waveform



T1 = 0.5 s
T2 = 3 s
Im = 15 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
				OUTLET					
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT			
1	9.83	———	4.728	4.659	4.85	0.19			
2		———		4.679	4.90	0.22	625		2255.8
3 cable	12.65	1.879		4.796	4.97	0.18	153.5	342.6	
3 corner		2.69		4.611	4.80	0.19	189.1		
4 corner		3.35		4.7	4.90	0.20	250	411.2	
4 cable		2.13		4.743	4.91	0.17	161.2		
5	20.2	———	4.557	4.613	4.82	0.21	877		
6		———		5.086	5.26	0.17			

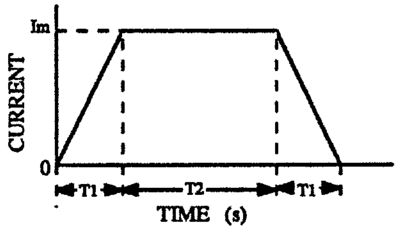
Run number 107 DM Shot number 219 Date 12/11/90 Time 16:11

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.52 g/s
Inlet pressure 6.311 atm
Inlet temperature 4.728 K

Bm 2.835 T
Tm .3 s
Bm/Tm 9.450 T/s
1/Tm 3.333 1/s
Im 15 kA
Flat top 3 s
Im/Tm 50.00 kA/s

Waveform



T1 = 0.3 s
T2 = 3 s
Im = 15 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
				OUTLET					
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT			
1	9.78	———	4.728	4.664	4.87	0.21			
2		———		4.678	4.93	0.25	708		2544
3 cable	12.64	1.9		4.795	5.00	0.20	178.2	394.2	
3 corner		2.71		4.609	4.82	0.22	216		
4 corner		3.36		4.699	4.93	0.23	282	470.8	
4 cable		2.15		4.742	4.94	0.20	188.8		
5	20.1	———	4.553	4.611	4.84	0.23	971		
6		———		5.089	5.28	0.19			

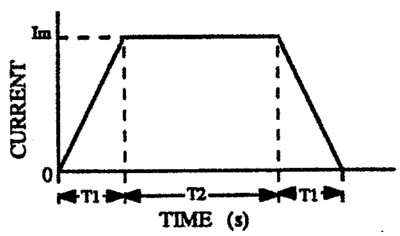
Run number 108 DM Shot number 224 Date 12/11/90 Time 16:23

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 41.35 g/s
Inlet pressure 6.331 atm
Inlet temperature 4.728 K

Bm 3.780 T
Tm 1.5 s
Bm/Tm 2.520 T/s
1/Tm 0.667 1/s
Im 20 kA
Flat top 3 s
Im/Tm 13.33 kA/s

Waveform



T1 = 1.5 s
T2 = 3 s
Im = 20 kA

Tm = T1

Quench ? No

Quench time _______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.23	———	4.728	4.665	4.91	0.24			
2		———		4.679	4.97	0.29	769		2951
3 cable	12.49	1.926		4.796	5.02	0.22	203	465	
3 corner		2.77		4.611	4.85	0.24	262		
4 corner		3.44		4.7	4.96	0.26	345	564	
4 cable		2.18		4.743	4.96	0.22	219		
5	19.63	———	4.555	4.612	4.88	0.27	1153		
6		———		5.09	5.33	0.24			

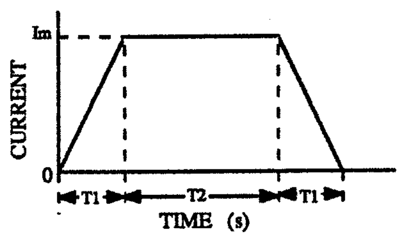
Run number 109 DM Shot number 225 Date 12/11/90 Time 16:36

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.54 g/s
Inlet pressure 6.331 atm
Inlet temperature 4.73 K

Bm 3.780 T
Tm 5 s
Bm/Tm 0.756 T/s
1/Tm 0.200 1/s
Im 20 kA
Flat top 3 s
Im/Tm 4.00 kA/s

Waveform



T1 = 5 s
T2 = 3 s
Im = 20 kA

Tm = T1

Quench ? No

Quench time _______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.77	———	4.73	4.667	4.84	0.18			
2		———		4.68	4.90	0.22	615		2331.6
3 cable	12.57	1.879		4.798	4.97	0.18	155	356	
3 corner		2.71		4.612	4.80	0.19	201		
4 corner		3.37		4.701	4.90	0.20	268	433.6	
4 cable		2.11		4.745	4.92	0.17	165.6		
5	20.2	———	4.557	4.614	4.83	0.21	927		
6		———		5.091	5.27	0.18			

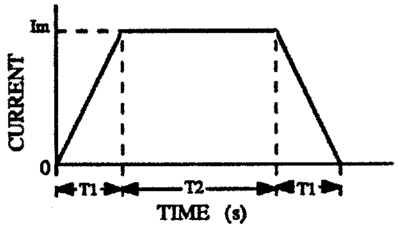
Run number 110 DM Shot number 220 Date 12/11/90 Time 16:46

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.54 g/s
Inlet pressure 6.331 atm
Inlet temperature 4.73 K

Bm 3.780 T
Tm 2 s
Bm/Tm 1.890 T/s
1/Tm 0.500 1/s
Im 20 kA
Flat top 3 s
Im/Tm 10.00 kA/s

Waveform



T1 = 2 s
T2 = 3 s

Im = 20 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.77	———	4.73	4.666	4.86	0.19			
2		———		4.681	4.92	0.24	672		2508
3 cable	12.57	1.879		4.799	4.99	0.19	168	383	
3 corner		2.71		4.614	4.82	0.21	215		
4 corner		3.37		4.701	4.92	0.22	286	465	
4 cable		2.11		4.746	4.93	0.19	179		
5	20.2	———	4.558	4.615	4.84	0.23	988		
6		———		5.091	5.27	0.18			

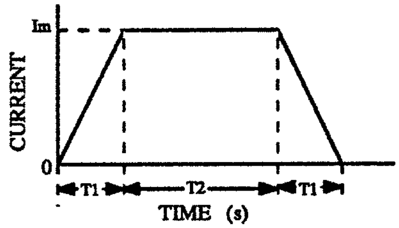
Run number 111 DM Shot number 221 Date 12/11/90 Time 16:58

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.57 g/s
Inlet pressure 6.287 atm
Inlet temperature 4.728 K

Bm 3.780 T
Tm 1 s
Bm/Tm 3.780 T/s
1/Tm 1.000 1/s
Im 20 kA
Flat top 3 s
Im/Tm 20.00 kA/s

Waveform



T1 = 1 s
T2 = 3 s

Im = 20 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.84	———	4.728	4.66	4.88	0.22			
2		———		4.68	4.95	0.27	779		2850
3 cable	12.63	1.895		4.796	5.02	0.22	198	442	
3 corner		2.71		4.612	4.85	0.24	244		
4 corner		3.38		4.701	4.96	0.25	323	533	
4 cable		2.14		4.744	4.96	0.21	210		
5	20.1	———	4.558	4.613	4.87	0.26	1096		
6		———		5.087	5.29	0.21			

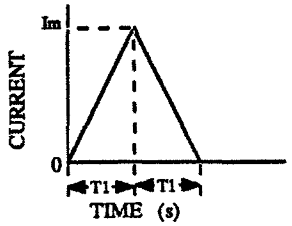
Run number 112 DM Shot number 256 Date 12/12/90 Time 9:57

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow X g/s
Inlet pressure 6.142 atm
Inlet temperature 4.728 K

Bm 0.284 T
Tm 5 s
Bm/Tm 0.057 T/s
1/Tm 0.200 1/s
Im 1.5 kA
Flat top 0 s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s
Im = 1.5 kA
Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT	
1	X	———	4.728	4.662			
2		———		4.681	4.68	0.00	X
3 cable	X	X		4.801			X
3 corner		X		4.61			X
4 corner		X		4.702	4.74	0.03	X
4 cable		X		4.747			X
5	X	———	4.555	4.614			X
6		———		5.1			

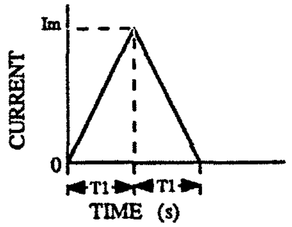
Run number 113 DM Shot number 257 Date 12/12/90 Time 10:07

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow X g/s
Inlet pressure 6.166 atm
Inlet temperature 4.728 K

Bm 0.284 T
Tm 5 s
Bm/Tm 0.057 T/s
1/Tm 0.200 1/s
Im 1.5 kA
Flat top 0 s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s
Im = 1.5 kA
Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT	
1	X	———	4.728	4.66			
2		———		4.68			X
3 cable	X	X		4.801			X
3 corner		X		4.61			X
4 corner		X		4.702	4.73	0.03	X
4 cable		X		4.746			X
5	X	———	4.553	4.613			X
6		———		5.095			

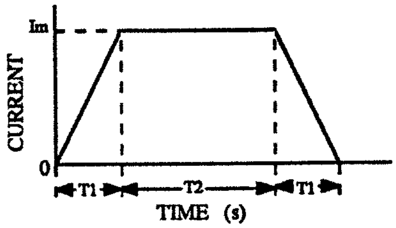
Run number 114 DM Shot number 258 Date 12/12/90 Time 10:17

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 44.04 g/s
Inlet pressure 6.190 atm
Inlet temperature 4.724 K

Bm 3.780 T
Tm .75 s
Bm/Tm 5.040 T/s
1/Tm 1.333 1/s
Im 20 kA
Flat top 3 s
Im/Tm 26.67 kA/s

Waveform



T1 = 0.75 s
T2 = 3 s
Im = 20 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.13	———	4.724	4.667	4.91	0.24			
2		———		4.68	4.98	0.30	875		3314
3 cable	13.01	2.23		4.801	5.04	0.24	264	570	
3 corner		3.15		4.612	4.86	0.25	306		
4 corner		3.59		4.702	4.98	0.27	369	643	
4 cable		2.52		4.748	4.98	0.23	274		
5	20.9	———	4.554	4.613	4.89	0.27	1226		
6		———		5.101	5.32	0.22			

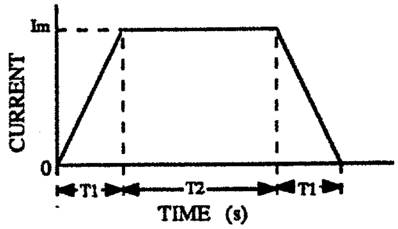
Run number 115 DM Shot number 259 Date 12/12/90 Time 10:28

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 44.09 g/s
Inlet pressure 6.190 atm
Inlet temperature 4.73 K

Bm 3.780 T
Tm .5 s
Bm/Tm 7.560 T/s
1/Tm 2.000 1/s
Im 20 kA
Flat top 3 s
Im/Tm 40.00 kA/s

Waveform



T1 = 0.5 s
T2 = 3 s
Im = 20 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.14	———	4.73	4.669	4.94	0.27			
2		———		4.691	5.01	0.32	979		3678
3 cable	13.05	2.27		4.801	5.07	0.27	312	644	
3 corner		3.15		4.615	4.90	0.28	332		
4 corner		3.6		4.702	5.01	0.30	405	715	
4 cable		2.53		4.748	5.01	0.26	310		
5	20.9	———	4.558	4.618	4.92	0.30	1340		
6		———		5.099	5.34	0.24			

Run number 116 DM Shot number 260 Date 12/12/90 Time 10:39

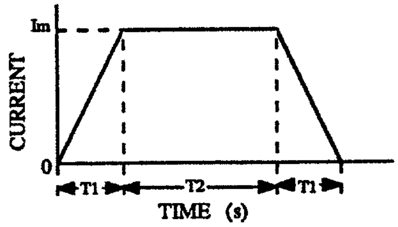
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 44.07 g/s
Inlet pressure 6.190 atm
Inlet temperature 4.73 K

Bm 3.780 T
Tm .3 s
Bm/Tm 12.600 T/s
1/Tm 3.333 1/s

Im 20 kA
Flat top 3 s
Im/Tm 66.67 kA/s

Waveform



T1 = 0.3 s
T2 = 3 s
Im = 20 kA

Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	ΔT			
1	10.1		4.73	4.668	4.98	0.31			
2				4.682	5.07	0.39	1160		4383
3 cable	13.07	2.38		4.801	5.12	0.31	400	791	
3 corner		3.17		4.616	4.95	0.33	391		
4 corner		3.6		4.703	5.06	0.36	472	861	
4 cable		2.59		4.75	5.05	0.30	389		
5	20.9		4.56	4.617	4.96	0.35	1571		
6				5.099	5.37	0.27			

Run number 117 DM Shot number X Date 12/12/90 Time 10:50

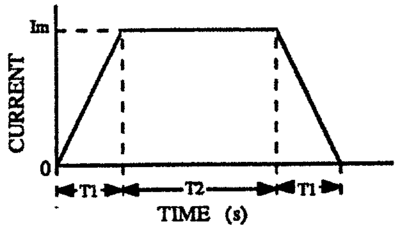
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow X g/s
Inlet pressure 6.166 atm
Inlet temperature 4.728 K

Bm 4.725 T
Tm 6 s
Bm/Tm 0.788 T/s
1/Tm 0.167 1/s

Im 25 kA
Flat top 3 s
Im/Tm 4.17 kA/s

Waveform



T1 = 6 s
T2 = 3 s
Im = 25 kA

Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	ΔT			
1	X		4.728	X					
2				X			X		
3 cable	X	X		X			X		
3 corner		X		X			X		
4 corner		X		X			X		
4 cable		X		X			X		
5	X		4.557	X			X		
6				X					

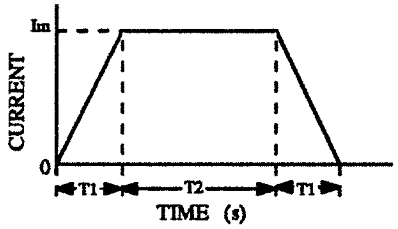
Run number 118 DM Shot number 261 Date 12/12/90 Time 10:58

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 43.74 g/s
Inlet pressure 6.166 atm
Inlet temperature 4.73 K

Bm 4.725 T
Tm 6 s
Bm/Tm 0.788 T/s
1/Tm 0.167 1/s
Im 25 kA
Flat top 33 s
Im/Tm 4.17 kA/s

Waveform



T1 = 6 s
T2 = 3 s
Im = 25 kA
Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.04	———	4.73	4.68	4.89	0.21			
2		———		4.671	4.95	0.27	785		3055
3 cable	12.8	2.24		4.801	5.01	0.21	228	516	
3 corner		3.14		4.615	4.84	0.23	288		
4 corner		3.56		4.704	4.95	0.24	349	595	
4 cable		2.53		4.748	4.96	0.21	246		
5	20.9	———	4.56	4.615	4.87	0.26	1159		
6		———		5.098	5.31	0.21			

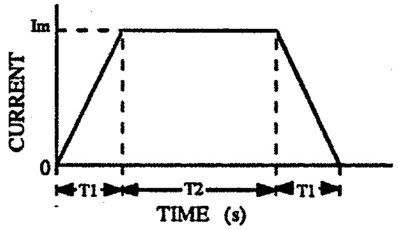
Run number 119 DM Shot number 262 Date 12/12/90 Time 11:09

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 43.74 g/s
Inlet pressure 6.166 atm
Inlet temperature 4.733 K

Bm 4.725 T
Tm 3 s
Bm/Tm 1.575 T/s
1/Tm 0.333 1/s
Im 25 kA
Flat top 3 s
Im/Tm 8.33 kA/s

Waveform



T1 = 3 s
T2 = 3 s
Im = 25 kA
Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.04	———	4.733	4.669	4.90	0.23			
2		———		4.684	4.97	0.29	836		3247
3 cable	12.8	2.24		4.803	5.04	0.23	246	552	
3 corner		3.14		4.618	4.87	0.25	306		
4 corner		3.56		4.707	4.97	0.27	369	633	
4 cable		2.53		4.75	4.98	0.23	264		
5	20.9	———	4.561	4.619	4.89	0.27	1226		
6		———		5.099	5.32	0.22			

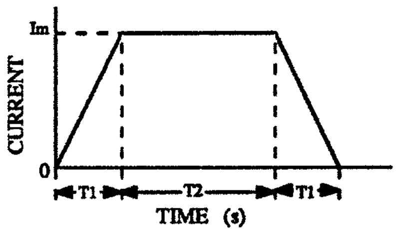
Run number 120 DM Shot number 277 Date 12/12/90 Time 11:21

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 43.96 g/s
Inlet pressure 6.142 atm
Inlet temperature 4.732 K

Bm 4.725 T
Tm 2 s
Bm/Tm 2.363 T/s
1/Tm 0.500 1/s
Im 25 kA
Flat top 3 s
Im/Tm 12.50 kA/s

Waveform



T1 = 2 s
T2 = 3 s
Im = 25 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.01	———	4.732	4.663	4.92	0.25			
2		———		4.681	5.00	0.31	901		3463
3 cable	13.05	2.25		4.801	5.05	0.25	266	591	
3 corner		3.14		4.615	4.88	0.27	325		
4 corner		3.57		4.705	5.00	0.29	392	676	
4 cable		2.54		4.75	4.99	0.24	284		
5	20.9	———	4.558	4.617	4.91	0.29	1295		
6		———		5.095	5.33	0.24			

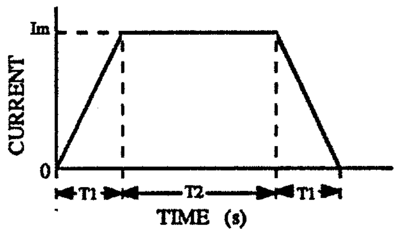
Run number 121 DM Shot number 274 Date 12/12/90 Time 11:31

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow X g/s
Inlet pressure 5.178 atm
Inlet temperature 4.732 K

Bm 4.725 T
Tm 1.5 s
Bm/Tm 3.150 T/s
1/Tm 0.667 1/s
Im 25 kA
Flat top 3 s
Im/Tm 16.67 kA/s

Waveform



T1 = 1.5 s
T2 = 3 s
Im = 25 kA
Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
Quench sequence ?
MC03, VB5-6, VB3-4, MC01

Quench time 1.58 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X	———	4.732	4.669	5.15	0.48			
2		———		4.682	5.33	0.65	X		
3 cable	X	X		4.8	5.40	0.60	X		
3 corner		X		4.615	5.24	0.63	X		
4 corner		X		4.703	5.49	0.79	X		
4 cable		X		4.748	5.41	0.66	X		
5	X	———	4.555	4.618	6.50	1.88	X		
6		———		5.116	6.30	1.18			

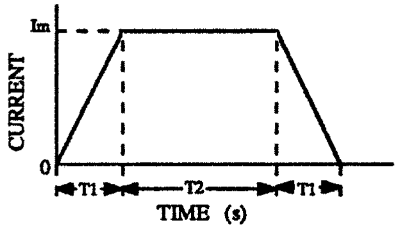
Run number 122 DM Shot number 275 Date 12/12/90 Time 11:43

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 43.58 g/s
Inlet pressure 6.142 atm
Inlet temperature 4.733 K

Bm 4.725 T
Tm 1.75 s
Bm/Tm 2.700 T/s
1/Tm 0.571 1/s
Im 25 kA
Flat top 3 s
Im/Tm 14.29 kA/s

Waveform



T1 = 1.75 s
T2 = 3 s
Im = 25 kA
Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.75	—	4.733	4.674	4.94	0.26			
2		—		4.688	5.01	0.32	953		3669
3 cable	13.03	2.24		4.806	5.07	0.26	286	631	
3 corner		3.14		4.62	4.90	0.28	345		
4 corner		3.56		4.709	5.01	0.30	412	715	
4 cable		2.54		4.755	5.01	0.25	303		
5	20.8	—	4.564	4.622	4.93	0.30	1370		
6		—		5.104	5.35	0.25			

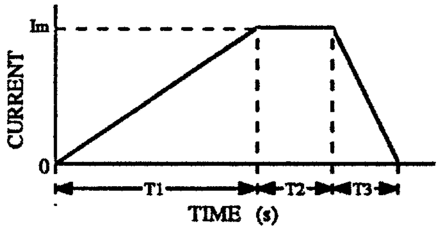
Run number 123 DM Shot number 276 Date 12/12/90 Time 13:19

Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 40.472 g/s
Inlet pressure 6.142 atm
Inlet temperature 4.741 K

Bm 5.670 T
Tm 11 s
Bm/Tm 0.515 T/s
1/Tm 0.091 1/s
Im 30 kA
Flat top 3 s
Im/Tm 2.73 kA/s

Waveform



T1 = 11 s
T2 = 3 s
T3 = 0.5 s
Im = 30 kA
Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	8.402	—	4.741	4.664	5.06	0.40			
2		—		4.688	5.19	0.50	1327		5569.8
3 cable	12.28	2.505		4.807	5.22	0.41	521.5	1080	
3 corner		3.276		4.624	5.06	0.44	558.5		
4 corner		3.689		4.713	5.19	0.47	662.2	1204.8	
4 cable		2.861		4.758	5.15	0.40	542.6		
5	19.79	—	4.571	4.625	5.07	0.45	1958		
6		—		5.1	5.46	0.36			

Run number 124 DM Shot number 283 Date 12/12/90 Time 13:31

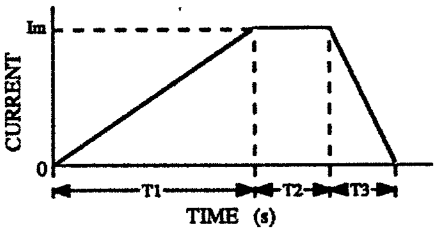
Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 39.085 g/s
Inlet pressure 6.166 atm
Inlet temperature 4.741 K

Bm 5.670 T
Tm 8 s
Bm/Tm 0.709 T/s
1/Tm 0.125 1/s

Im 30 kA
Flat top 3 s
Im/Tm 3.75 kA/s

Waveform



T1 = 8 s
T2 = 3 s
T3 = 0.5 s

Im = kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	7.615	—	4.741	4.675	5.08	0.40			
2		—		4.687	5.20	0.51	1244		5591.6
3 cable	12.01	2.607		4.81	5.22	0.41	555.7	1135.9	
3 corner		3.356		4.625	5.07	0.44	580.2		
4 corner		3.75		4.714	5.20	0.48	682.8	1256.7	
4 cable		2.941		4.76	5.17	0.41	573.9		
5	19.46	—	4.568	4.625	5.09	0.46	1955		
6		—		5.106	5.47	0.36			

Run number 125 DM Shot number 263 Date 12/12/90 Time 13:42

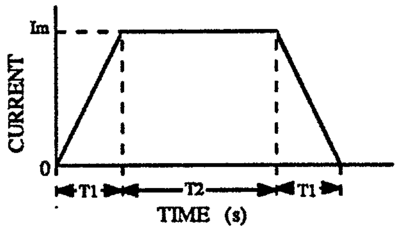
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 37.518 g/s
Inlet pressure 5.251 atm
Inlet temperature 4.743 K

Bm 5.670 T
Tm 6 s
Bm/Tm 0.945 T/s
1/Tm 0.167 1/s

Im 30 kA
Flat top 3 s
Im/Tm 5.00 kA/s

Waveform



T1 = 6 s
T2 = 3 s

Im = 30 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6,MC03,VB1-2,MC01

Quench time 5.86 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	6.87	—	4.743	4.679	5.27	0.59			
2		—		4.69	5.52	0.83	2101		19803
3 cable	11.715	2.779		4.814	5.65	0.84	1214	2470	
3 corner		3.422		4.625	5.50	0.88	1256		
4 corner		3.814		4.718	5.83	1.11	1719	3162	
4 cable		3.089		4.762	5.70	0.94	1443		
5	18.933	—	4.574	4.633	7.26	2.63	12070		
6		—		5.112	6.68	1.57			

Run number 126 DM Shot number 278 Date 12/12/90 Time 13:53

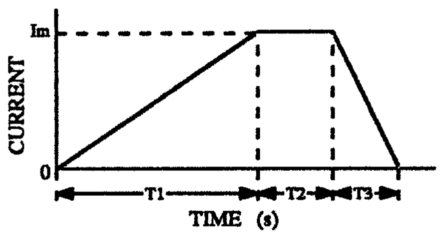
Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 37.427 g/s
Inlet pressure 5.124 atm
Inlet temperature 4.747 K

Bm 5.670 T
Tm 7 s
Bm/Tm 0.810 T/s
1/Tm 0.143 1/s

Im 30 kA
Flat top 3 s
Im/Tm 4.29 kA/s

Waveform



T1 = 7 s
T2 = 3 s
T3 = 0.5 s

Im = 30 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6,MC03,VB1-2,MC01

Quench time 6.85 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	6.304	—	4.747	4.665	5.26	0.60			
2		—		4.685	5.53	0.84	1992		22365
3 cable	11.914	2.725		4.819	5.67	0.85	1229	2531	
3 corner		3.395		4.632	5.53	0.90	1302		
4 corner		3.789		4.722	5.89	1.17	1834	3341	
4 cable		3.053		4.765	5.75	0.98	1507		
5	19.209	—	4.577	4.636	7.65	3.01	14501		
6		—		5.114	6.84	1.73			

Run number 127 DM Shot number 279 Date 12/12/90 Time 14:04

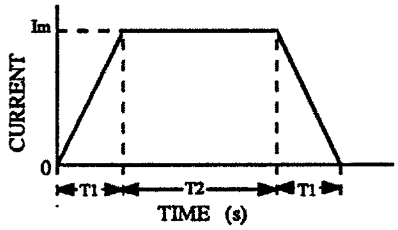
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.57 g/s
Inlet pressure 6.098 atm
Inlet temperature 4.745 K

Bm 4.158 T
Tm 1 s
Bm/Tm 4.158 T/s
1/Tm 1.000 1/s

Im 22 kA
Flat top 3 s
Im/Tm 22.00 kA/s

Waveform



T1 = 1 s
T2 = 3 s

Im = 22 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	8.52	—	4.745	4.679	4.92	0.25			
2		—		4.686	5.00	0.31	946		3665
3 cable	13.15	2.29		4.818	5.07	0.25	302	647	
3 corner		3.16		4.63	4.90	0.27	345		
4 corner		3.58		4.72	5.02	0.30	407	713	
4 cable		2.55		4.765	5.01	0.25	306		
5	20.9	—	4.574	4.634	4.93	0.30	1359		
6		—		5.119	4.35				

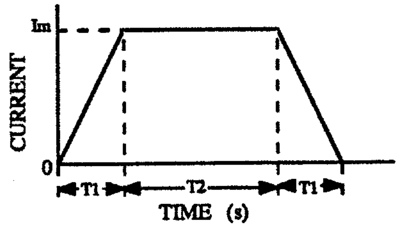
Run number 128 DM Shot number 280 Date 12/12/90 Time 14:15

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.38 g/s
Inlet pressure 6.524 atm
Inlet temperature 4.775 K

Bm 4.347 T Im 23 kA
Tm 1 s Flat top 3 s
Bm/Tm 4.347 T/s Im/Tm 23.00 kA/s
1/Tm 1.000 1/s

Waveform



T1 = 1 s
T2 = 3 s

Im = 23 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
			INLET	OUTLET					
	INLET	OUTLET		INITIAL	PEAK	ΔT			
1	8.48	———	4.775	4.695	4.97	0.27			
2		———		4.719	5.06	0.34	1050		4110
3 cable	13.1	2.22		4.85	5.13	0.28	337	727	
3 corner		3.12		4.668	4.96	0.29	390		
4 corner		3.59		4.761	5.08	0.32	467	811	
4 cable		2.46		4.8	5.07	0.27	344		
5	20.8	———	4.61	4.675	4.99	0.32	1522		
6		———		5.142	4.40				

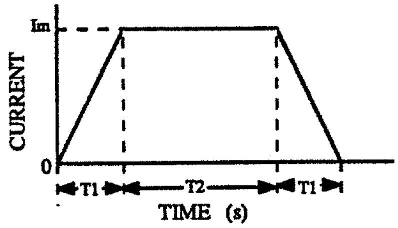
Run number 129 DM Shot number 264 Date 12/12/90 Time 14:25

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 35.341 g/s
Inlet pressure 5.763 atm
Inlet temperature 4.801 K

Bm 4.536 T Im 24 kA
Tm 1 s Flat top 3 s
Bm/Tm 4.536 T/s Im/Tm 24.00 kA/s
1/Tm 1.000 1/s

Waveform



T1 = 1 s
T2 = 3 s

Im = 24 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
MC03,VB5-6,VB1-2,VB3-4,MC01

Quench time 1.1 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
			INLET	OUTLET					
	INLET	OUTLET		INITIAL	PEAK	ΔT			
1	8.681	———	4.801	4.718	5.15	0.43			
2		———		4.742	5.33	0.59	1879		8958.9
3 cable	13.574	2.545		4.869	5.42	0.55	739.6	1484.1	
3 corner		3.263		4.685	5.26	0.58	744.5		
4 corner		3.692		4.779	5.50	0.72	975.9	1770.8	
4 cable		2.754		4.819	5.42	0.60	794.9		
5	13.086	———	4.633	4.578	6.35	1.77	3825		
6		———		4.694	6.18	1.49			

Run number 130 DM Shot number 265 Date 12/12/90 Time 14:36

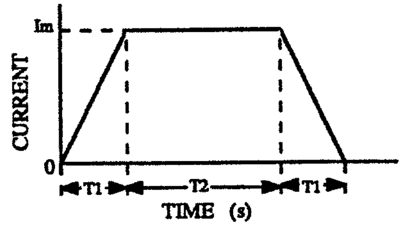
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow X g/s
Inlet pressure 5.215 atm
Inlet temperature 4.741 K

Bm 4.347 T
Tm 1 s
Bm/Tm 4.347 T/s
1/Tm 1.000 1/s

Im 23 kA
Flat top 13 s
Im/Tm 23.00 kA/s

Waveform



T1 = 1 s
T2 = 13 s

Im = 23 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6,MC03,MC01

Quench time 1.3 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT			
1	X	—	4.741	4.677	5.09	0.41			
2		—		4.686	5.25	0.56	X		
3 cable	X	X		4.814	5.36	0.54	X		
3 corner		X		4.625	5.20	0.57	X		
4 corner		X		4.714	5.48	0.77	X		
4 cable		X		4.761	5.40	0.64	X		
5	X	—	4.574	4.629	6.95	2.32	X		
6		—		5.112	6.56	1.45			

Run number 131 DM Shot number 266 Date 12/12/90 Time 14:46

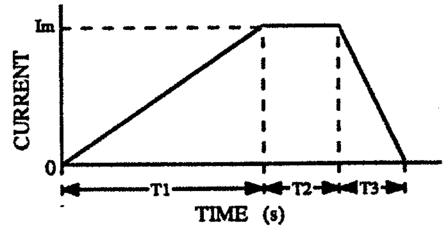
Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 39.352 g/s
Inlet pressure 6.026 atm
Inlet temperature 4.732 K

Bm 5.859 T
Tm 11 s
Bm/Tm 0.533 T/s
1/Tm 0.091 1/s

Im 31 kA
Flat top 3 s
Im/Tm 2.82 kA/s

Waveform



T1 = 11 s
T2 = 3 s
T3 = 0.5 s

Im = 31 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT			
1	6.882	—	4.732	4.654	5.07	0.42			
2		—		4.67	5.21	0.54	1249		5612
3 cable	12.41	2.559		4.805	5.25	0.44	542	1123	
3 corner		3.332		4.617	5.08	0.47	581		
4 corner		3.748		4.709	5.22	0.51	678	1234	
4 cable		2.889		4.752	5.18	0.43	556		
5	20.06	—	4.561	4.621	5.10	0.48	2006		
6		—		5.101	5.49	0.38			

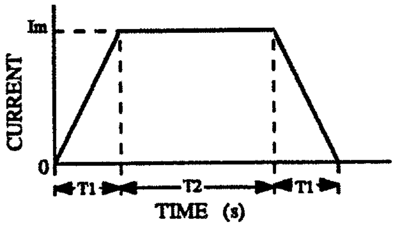
Run number 132 DM Shot number 281 Date 12/12/90 Time 15:33

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 43.666 g/s
Inlet pressure 6.166 atm
Inlet temperature 4.336 K

Bm 4.347 T
Tm 1 s
Bm/Tm 4.347 T/s
1/Tm 1.000 1/s
Im 23 kA
Flat top 3 s
Im/Tm 23.00 kA/s

Waveform



T1 = 1 s
T2 = 3 s

Im = 23 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	8.656	———	4.336	4.369	4.63	0.26			
2		———		4.316	4.64	0.33	1549		7874
3 cable	13.53	2.353		4.499	4.76	0.26	903	1173	
3 corner		3.308		4.282	4.57	0.29	270		
4 corner		3.71		4.355	4.67	0.32	2386	4042	
4 cable		2.596		4.429	4.69	0.26	1656		
5	21.48	———	4.153	4.26	4.58	0.32	1110		
6		———		4.814	5.05	0.24			

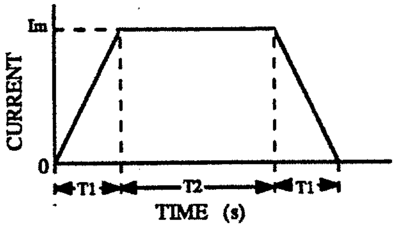
Run number 133 DM Shot number 267 Date 12/12/90 Time 15:45

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.28 g/s
Inlet pressure 5.11 atm
Inlet temperature 4.271 K

Bm 4.536 T
Tm 1 s
Bm/Tm 4.536 T/s
1/Tm 1.000 1/s
Im 24 kA
Flat top 3 s
Im/Tm 24.00 kA/s

Waveform



T1 = 1 s
T2 = 3 s

Im = 24 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
MC03,VB5-6,VB1-2,VB3-4,MC01

Quench time 1.13 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	8.28	———	4.271	4.301	4.80	0.49			
2		———		4.244	4.92	0.67	1925		8411
3 cable	13.2	2.35		4.433	5.07	0.63	753	1524	
3 corner		3.23		4.213	4.90	0.68	771		
4 corner		3.62		4.277	5.18	0.90	1062	1912	
4 cable		2.58		4.361	5.11	0.74	850		
5	20.8	———	4.086	4.187	6.49	2.30	3050		
6		———		4.749	6.22	1.47			

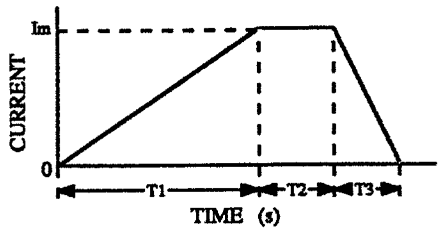
Run number 134 DM Shot number 268 Date 12/12/90 Time 16:02

Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 39.268 g/s
Inlet pressure 6.142 atm
Inlet temperature 4.258 K

Bm 6.048 T Im 32 kA
Tm 11 s Flat top 3 s
Bm/Tm 0.550 T/s Im/Tm 2.91 kA/s
1/Tm 0.091 1/s

Waveform



T1 = 11 s
T2 = 3 s
T3 = 0.5 s

Im = 32 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	6.908	—	4.258	4.281	4.79	0.51			
2		—		4.223	4.88	0.66	1326		5999.5
3 cable	12.4	2.553		4.419	4.96	0.54	573.4	1202.2	
3 corner		3.331		4.199	4.78	0.58	628.8		
4 corner		3.712		4.262	4.89	0.63	721.3	1302.3	
4 cable		2.866		4.349	4.87	0.52	581		
5	19.96	—	4.073	4.182	4.79	0.60	2169		
6		—		4.731	5.20	0.46			

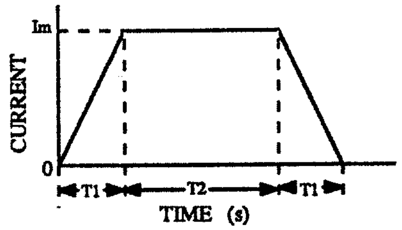
Run number 135 DM Shot number 269 Date 12/12/90 Time 16:14

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow X g/s
Inlet pressure 5.135 atm
Inlet temperature 4.261 K

Bm 5.198 T Im 27.5 kA
Tm 4 s Flat top 3 s
Bm/Tm 1.300 T/s Im/Tm 6.88 kA/s
1/Tm 0.250 1/s

Waveform



T1 = 4 s
T2 = 3 s

Im = 27.5 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6,MC03,VB3-4,MC01

Quench time 4.04 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X	—	4.261	4.309	4.90	0.59			
2		—		4.227	5.08	0.85	X		
3 cable	X	X		4.423	5.24	0.82	X		
3 corner		X		4.202	5.08	0.88	X		
4 corner		X		4.264	5.39	1.13	X		
4 cable		X		4.352	5.30	0.94	X		
5	X	—	4.076	4.185	6.76	2.58	X		
6		—		4.735	6.40	1.67			

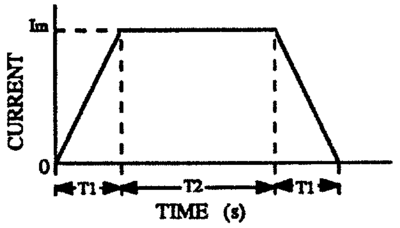
Run number 136 DM Shot number 282 Date 12/12/90 Time 16:25

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 24.279 g/s
Inlet pressure 6.074 atm
Inlet temperature 4.268 K

Bm 5.198 T
Tm 5 s
Bm/Tm 1.040 T/s
1/Tm 0.200 1/s
Im 27.5 kA
Flat top 3 s
Im/Tm 5.50 kA/s

Waveform



T1 = 5 s
T2 = 3 s
Im = 27.5 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	6.221		4.268	4.301	4.57	0.27			
2				4.235	4.58	0.34	615		2147
3 cable	4.426	1.036		4.429	4.71	0.28	114	303	
3 corner		1.86		4.208	4.51	0.30	189		
4 corner		2.013		4.272	4.60	0.33	212	397	
4 cable		1.781		4.359	4.64	0.28	185		
5	13.632		4.083	4.194	4.54	0.35	832		
6				4.746	5.02	0.28			

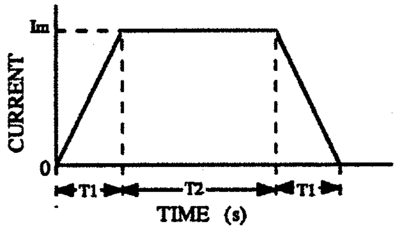
Run number 137 DM Shot number 270 Date 12/12/90 Time 16:38

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.28 g/s
Inlet pressure 6.074 atm
Inlet temperature 4.267 K

Bm 3.402 T
Tm .2 s
Bm/Tm 17.010 T/s
1/Tm 5.000 1/s
Im 18 kA
Flat top 3 s
Im/Tm 90.00 kA/s

Waveform



T1 = 0.2 s
T2 = 3 s
Im = 18 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	8.28		4.267	4.294	4.63	0.33			
2				4.23	4.66	0.43	1014		3868
3 cable	13.2	2.35		4.428	4.77	0.34	331	702	
3 corner		3.23		4.205	4.58	0.38	371		
4 corner		3.62		4.269	4.68	0.41	429	754	
4 cable		2.58		4.355	4.70	0.34	325		
5	20.8		4.081	4.19	4.58	0.39	1398		
6				4.736	5.04	0.30			

Run number 138 DM Shot number 271 Date 12/12/90 Time 16:49

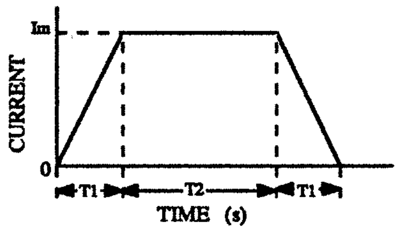
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 41.99 g/s
Inlet pressure 6.098 atm
Inlet temperature 4.266 K

Bm 3.591 T
Tm .2 s
Bm/Tm 17.955 T/s
1/Tm 5.000 1/s

Im 19 kA
Flat top 3 s
Im/Tm 95.00 kA/s

Waveform



T1 = 0.2 s
T2 = 3 s
Im = 19 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	8.2	—	4.266	4.287	4.65	0.36			
2		—		4.229	4.70	0.47	1109		4254
3 cable	13.19	2.39		4.425	4.80	0.38	386	789	
3 corner		3.2		4.205	4.62	0.41	403		
4 corner		3.63		4.268	4.72	0.45	471	835	
4 cable		2.58		4.355	4.73	0.37	364		
5	20.6	—	4.08	4.189	4.61	0.42	1521		
6		—		4.735	5.06	0.32			

Run number 139 DM Shot number 272 Date 12/12/90 Time 16:59

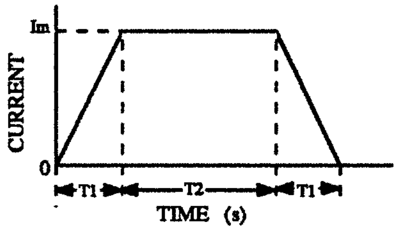
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.46 g/s
Inlet pressure 6.074 atm
Inlet temperature 4.262 K

Bm 3.780 T
Tm .2 s
Bm/Tm 18.900 T/s
1/Tm 5.000 1/s

Im 20 kA
Flat top 3 s
Im/Tm 100.00 kA/s

Waveform



T1 = 0.2 s
T2 = 3 s
Im = 20 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	8.31	—	4.262	4.292	4.69	0.40			
2		—		4.228	4.75	0.52	1280		4901
3 cable	13.25	2.45		4.423	4.84	0.42	459	911	
3 corner		3.2		4.204	4.66	0.46	452		
4 corner		3.63		4.267	4.76	0.49	528	968	
4 cable		2.64		4.353	4.76	0.41	440		
5	20.9	—	4.077	4.188	4.66	0.47	1742		
6		—		4.736	5.09	0.36			

Run number 140 DM Shot number 273 Date 12/13/90 Time 10:20

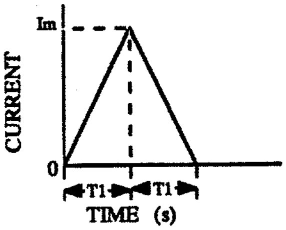
Connection Single coil
Mode AC
Description Single triangle

Total inlet flow X g/s
Inlet pressure 5.910 atm
Inlet temperature 4.357 K

Bm 0.284 T
Tm 5 s
Bm/Tm 0.057 T/s
1/Tm 0.200 1/s

Im 1.5 kA
Flat top 0 s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s
Im = 1.5 kA
Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]
				OUTLET			
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT	
1	X	—	4.357	4.384			
2		—		4.35			X
3 cable	X	X		4.495			X
3 corner		X		4.277			X
4 corner		X		4.346	4.38	0.04	X
4 cable		X		4.42			X
5	X	—	4.176	4.264			X
6		—		4.799			

Run number 141 DM Shot number 284 Date 12/13/90 Time 10:28

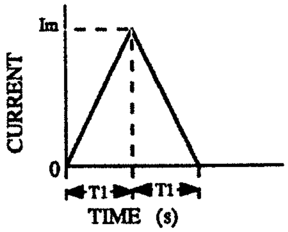
Connection Single coil
Mode AC
Description Single triangle

Total inlet flow X g/s
Inlet pressure 5.885 atm
Inlet temperature 4.358 K

Bm 0.284 T
Tm 5 s
Bm/Tm 0.057 T/s
1/Tm 0.200 1/s

Im 1.5 kA
Flat top 0 s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s
Im = 1.5 kA
Tm = T1

Quench ? ______

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]
				OUTLET			
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT	
1	X	—	4.358	4.385			
2		—		4.351			X
3 cable	X	X		4.495			X
3 corner		X		4.278			X
4 corner		X		4.346			X
4 cable		X		4.421			X
5	X	—	4.176	4.265			X
6		—		4.8			

Run number 142 DM Shot number 285 Date 12/13/90 Time 10:38

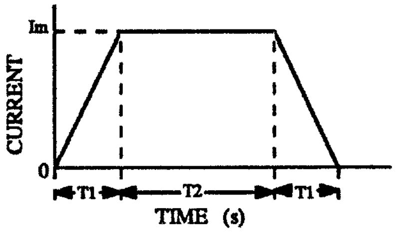
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 43.56 g/s
Inlet pressure 5.885 atm
Inlet temperature 4.361 K

Bm 4.158 T
Tm 5 s
Bm/Tm 0.832 T/s
1/Tm 0.200 1/s

Im 22 kA
Flat top 3 s
Im/Tm 4.40 kA/s

Waveform



T1 = 5 s
T2 = 3 s

Im = 22 kA

Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.17	———	4.361	4.393	4.62	0.22			
2		———		4.353	4.62	0.26	671		2643
3 cable	12.41	2.15		4.495	4.71	0.21	194	443	
3 corner		3.02		4.279	4.52	0.24	249		
4 corner		3.41		4.347	4.60	0.25	304	514	
4 cable		2.42		4.422	4.64	0.22	210		
5	19.98	———	4.178	4.255	4.52	0.26	1015		
6		———		4.8	5.01	0.21			

Run number 143 DM Shot number 286 Date 12/13/90 Time 10:49

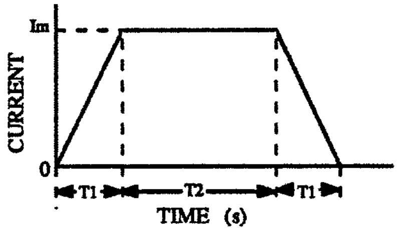
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 43.56 g/s
Inlet pressure 5.929 atm
Inlet temperature 4.364 K

Bm 4.158 T
Tm 2 s
Bm/Tm 2.079 T/s
1/Tm 0.500 1/s

Im 22 kA
Flat top 3 s
Im/Tm 11.00 kA/s

Waveform



T1 = 2 s
T2 = 3 s

Im = 22 kA

Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.17	———	4.364	4.393	4.64	0.25			
2		———		4.36	4.66	0.30	731		2837
3 cable	12.41	2.15		4.5	4.74	0.24	209	476	
3 corner		3.02		4.285	4.55	0.26	267		
4 corner		3.41		4.353	4.64	0.28	323	549	
4 cable		2.42		4.428	4.67	0.24	226		
5	19.98	———	4.181	4.26	4.55	0.29	1081		
6		———		4.803	5.03	0.23			

Run number 144 DM Shot number 291 Date 12/13/90 Time 11:01

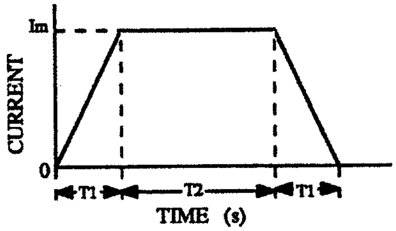
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 43.71 g/s
Inlet pressure 6.002 atm
Inlet temperature 4.367 K

Bm 4.158 T
Tm 1.5 s
Bm/Tm 2.772 T/s
1/Tm 0.667 1/s

Im 22 kA
Flat top 3 s
Im/Tm 14.67 kA/s

Waveform



T1 = 1.5 s
T2 = 3 s

Im = 22 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT			
1	11.23		4.367	4.401	4.67	0.27			
2				4.361	4.68	0.32	792		3042
3 cable	12.45	2.14		4.501	4.76	0.26	226	512	
3 corner		3.04		4.288	4.57	0.28	286		
4 corner		3.44		4.355	4.66	0.30	347	589	
4 cable		2.39		4.431	4.69	0.26	242		
5	20.03		4.185	4.264	4.57	0.30	1149		
6				4.808	5.05	0.24			

Run number 145 DM Shot number 292 Date 12/13/90 Time 11:12

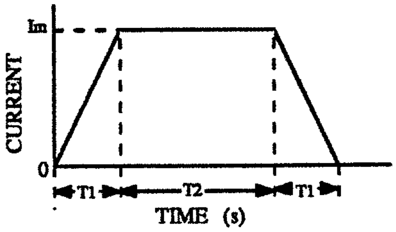
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 43.93 g/s
Inlet pressure 6.050 atm
Inlet temperature 4.37 K

Bm 4.158 T
Tm .75 s
Bm/Tm 5.544 T/s
1/Tm 1.333 1/s

Im 22 kA
Flat top 3 s
Im/Tm 29.33 kA/s

Waveform



T1 = 0.75 s
T2 = 3 s

Im = 22 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT			
1	11.3		4.37	4.404	4.71	0.31			
2				4.366	4.74	0.38	958		3783
3 cable	12.53	2.16		4.505	4.81	0.31	295	622	
3 corner		3		4.291	4.62	0.33	327		
4 corner		3.43		4.36	4.72	0.36	572	866	
4 cable		2.39		4.434	4.73	0.30	294		
5	20.1		4.189	4.268	4.62	0.35	1337		
6				4.81	5.08	0.27			

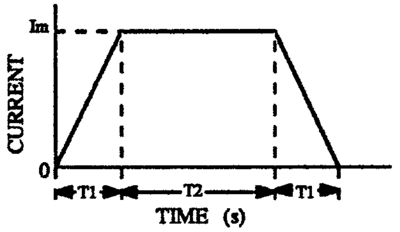
Run number 146 DM Shot number 293 Date 12/13/90 Time 11:22

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 43.85 g/s
Inlet pressure 6.074 atm
Inlet temperature 4.371 K

Bm 4.158 T
Tm .5 s
Bm/Tm 8.316 T/s
1/Tm 2.000 1/s
Im 22 kA
Flat top 3 s
Im/Tm 44.00 kA/s

Waveform



T1 = 0.5 s
T2 = 3 s

Im = 22 kA

Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.27	______	4.371	4.404	4.75	0.35			
2		______		4.366	4.80	0.43	1117		4469
3 cable	12.48	2.22		4.506	4.86	0.35	364	731	
3 corner		2.98		4.292	4.67	0.38	367		
4 corner		3.42		4.36	4.77	0.41	447	821	
4 cable		2.46		4.435	4.78	0.34	374		
5	20.1	______	4.191	4.269	4.66	0.39	1800		
6		______		4.81	5.11	0.30			

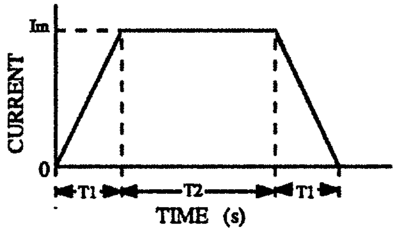
Run number 147 DM Shot number 294 Date 12/13/90 Time 11:33

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow X g/s
Inlet pressure 5.135 atm
Inlet temperature 4.372 K

Bm 4.158 T
Tm .3 s
Bm/Tm 13.860 T/s
1/Tm 3.333 1/s
Im 22 kA
Flat top 3 s
Im/Tm 73.33 kA/s

Waveform



T1 = 0.3 s
T2 = 3 s

Im = 22 kA

Tm = T1

Quench ? Yes- Coil C initiated from joint.

Quench detection sequence
VB3-4,MC02,MC01

Quench time – s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X	______	4.372	4.401	4.90	0.50			
2		______		4.368	5.01	0.64	X		
3 cable	X	X		4.521	33.20	28.68	X		
3 corner		X		4.31	14.15	9.84	X		
4 corner		X		4.361	4.99	0.63	X		
4 cable		X		4.435	4.96	0.53	X		
5	X	______	4.191	4.27	4.85	0.58	X		
6		______		4.806	5.22	0.42			

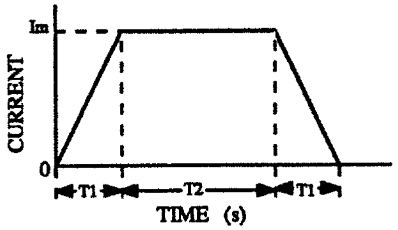
Run number 148 DM Shot number 287 Date 12/13/90 Time 11:48

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow X g/s
Inlet pressure 5.124 atm
Inlet temperature 4.375 K

Bm 3.969 T
Tm .2 s
Bm/Tm 19.845 T/s
1/Tm 5.000 1/s
Im 21 kA
Flat top 3 s
Im/Tm 105.00 kA/s

Waveform



T1 = 0.2 s
T2 = 3 s

Im = 21 kA

Tm = T1

Quench ? Yes- Coil C initiated from joint.

Quench detection sequence
VB3-4,VB1-2,MC02,MC01

Quench time -- s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X	———	4.375	4.403	4.91	0.51			
2		———		4.368	5.02	0.65	X		
3 cable	X	X		4.519	37.00	32.48	X		
3 corner		X		4.31	15.35	11.04	X		
4 corner		X		4.358	4.98	0.62	X		
4 cable		X		4.437	4.96	0.52	X		
5	X	———	4.193	4.27	4.85	0.58	X		
6		———		4.809	5.23	0.42			

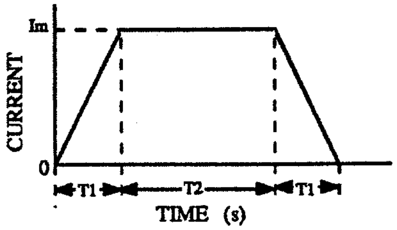
Run number 149 DM Shot number 288 Date 12/13/90 Time 13:16

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 43.57 g/s
Inlet pressure 6.050 atm
Inlet temperature 4.371 K

Bm 2.835 T
Tm .2 s
Bm/Tm 14.175 T/s
1/Tm 5.000 1/s
Im 15 kA
Flat top 3 s
Im/Tm 75.00 kA/s

Waveform



T1 = 0.2 s
T2 = 3 s

Im = 15 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.21	———	4.371	4.396	4.67	0.27			
2		———		4.363	4.68	0.32	779.1		2857.8
3 cable	12.45	2.09		4.505	4.76	0.26	218	478.3	
3 corner		2.96		4.292	4.57	0.28	260.3		
4 corner		3.371		4.359	4.66	0.30	316.9	543.4	
4 cable		2.351		4.435	4.68	0.25	226.5		
5	19.91	———	4.191	4.268	4.56	0.29	1057		
6		———		4.803	5.03	0.23			

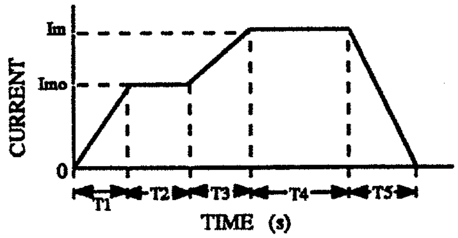
Run number 150 DM Shot number 289 Date 12/13/90 Time 13:27

Connection ______
Mode ______
Description Two-step trapezoid

Total inlet flow 40.864 g/s
Inlet pressure 6.074 atm
Inlet temperature 4.369 K

Bm 5.103 T
Tm 3 s
Bm/Tm 1.701 T/s
1/Tm 0.333 1/s
Im 27 kA
Flat top 3 s
Im/Tm 9.00 kA/s

Waveform



T1 = 1 s
T2 = 1 s
T3 = 1 s
T4 = 3 s
T5 = 1 s

Im = 22 kA
Imo = 27 kA

Tm = T1+T2+T3

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.504	——	4.369	4.401	4.77	0.37			
2		——		4.365	4.81	0.45	968.9		4141.4
3 cable	11.36	2.179		4.506	4.87	0.36	345.3	744.7	
3 corner		3.012		4.29	4.69	0.40	399.4		
4 corner		3.399		4.358	4.78	0.42	479.7	834.8	
4 cable		2.409		4.435	4.79	0.36	355.1		
5	20	——	4.189	4.266	4.68	0.41	1593		
6		——		4.805	5.13	0.32			

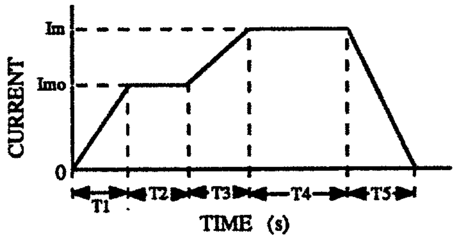
Run number 151 DM Shot number 290 Date 12/13/90 Time 13:37

Connection Single coil
Mode AC
Description Two-step trapezoid

Total inlet flow 43.69 g/s
Inlet pressure 6.050 atm
Inlet temperature 4.37 K

Bm 5.670 T
Tm 3 s
Bm/Tm 1.890 T/s
1/Tm 0.333 1/s
Im 30 kA
Flat top 3 s
Im/Tm 10.00 kA/s

Waveform



T1 = 1 s
T2 = 1 s
T3 = 1 s
T4 = 3 s
T5 = 1 s

Im = 22 kA
Imo = 30 kA

Tm = T1+T2+T3

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.23	——	4.37	4.402	4.82	0.42			
2		——		4.365	4.88	0.52	1339		5022.4
3 cable	12.5	2.176		4.505	4.93	0.43	411.8	866.5	
3 corner		2.954		4.294	4.75	0.46	454.7		
4 corner		3.38		4.357	4.85	0.49	553.4	972.9	
4 cable		2.387		4.435	4.85	0.42	419.5		
5	19.96	——	4.19	4.269	4.74	0.47	1844		
6		——		4.806	5.17	0.36			

Run number 152 DM Shot number 295 Date 12/13/90 Time 13:49

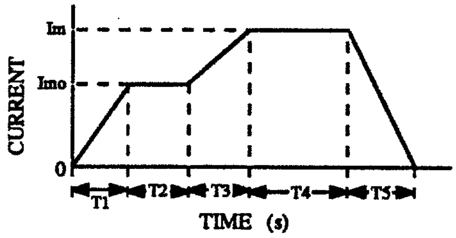
Connection Single coil
Mode AC
Description Two-step trapezoid

Total inlet flow 22.917 g/s
Inlet pressure 5.184 atm
Inlet temperature 4.374 K

Bm 5.670 T
Tm 2 s
Bm/Tm 2.835 T/s
1/Tm 0.500 1/s

Im 30 kA
Flat top 3 s
Im/Tm 15.00 kA/s

Waveform



T1 = 0.73 s
T2 = 1 s
T3 = 0.27 s
T4 = 3 s
T5 = 1 s

Im = 22 kA
Imo = 30 kA

Tm = T1+T2+T3

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6,MC03,VB3-4,MC02,MC01

Quench time 1.97 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
				OUTLET					
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT			
1	9.25	———	4.374	4.4	5.20	0.80			
2		———		4.37	5.63	1.26	3020		31373
3 cable	5.641	3.166		4.501	6.57	2.07	3373	6828	
3 corner		3.63		4.3	6.44	2.14	3455		
4 corner		3.763		4.364	7.43	3.07	5786	10699	
4 cable		3.635		4.445	6.87	2.43	4913		
5	8.026	———	4.194	4.27	9.70	5.43	10826		
6		———		4.7	7.32	2.62			

Run number 153 DM Shot number 296 Date 12/13/90 Time 14:02

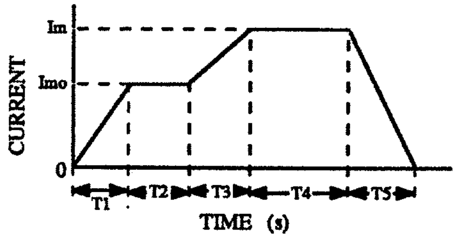
Connection Single coil
Mode AC
Description Two-step trapezoid

Total inlet flow 23.219 g/s
Inlet pressure 5.043 atm
Inlet temperature 4.385 K

Bm 5.670 T
Tm 4 s
Bm/Tm 1.418 T/s
1/Tm 0.250 1/s

Im 30 kA
Flat top 3 s
Im/Tm 7.50 kA/s

Waveform



T1 = 0.73 s
T2 = 3 s
T3 = 0.27 s
T4 = 3 s
T5 = 1 s

Im = 22 kA
Imo = 30 kA

Tm = T1+T2+T3

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6,VB3-4,MC03,MC02,MC01

Quench time 4.04 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
				OUTLET					
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT			
1	10.065	———	4.385	4.415	5.23	0.82			
2		———		4.377	5.90	1.52	4038		42394
3 cable	4.804	3.427		4.503	7.36	2.86	6114	12875	
3 corner		3.262		4.3	7.90	3.60	6761		
4 corner		3.678		4.397	8.94	4.54	8771	15043	
4 cable		3.584		4.45	7.10	2.65	6272		
5	8.35	———	4.203	4.279	9.26	4.98	10438		
6		———		4.826	7.04	2.21			

Run number 154 DM Shot number 297 Date 12/13/90 Time 14:15

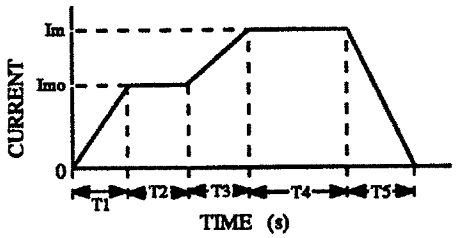
Connection Single coil
Mode AC
Description Two-step trapezoid

Total inlet flow 27.288 g/s
Inlet pressure 5.038 atm
Inlet temperature 4.382 K

Bm 5.670 T
Tm 4.47 s
Bm/Tm 1.268 T/s
1/Tm 0.224 1/s

Im 30 kA
Flat top 3 s
Im/Tm 6.71 kA/s

Waveform



T1 = 0.73 s
T2 = 3 s
T3 = 0.75 s
T4 = 3 s
T5 = 1 s

Im = 22 kA
Imo = 30 kA

Tm = T1+T2+T3

Quench ? Yes- Coils B and C crossover turns.

Quench detection sequence
VB5-6,VB3-4,MC02, MC03

Quench time 4.42 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
				OUTLET					
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT			
1	11.759	———	4.382	4.421	5.22	0.79			
2		———		4.379	5.83	1.45	4768		59184
3 cable	4.549	3.185		4.523	8.22	3.70	10041	21494	
3 corner		3.455		4.306	8.97	4.66	11453		
4 corner		3.502		4.368	9.90	5.53	12200	22031	
4 cable		3.572		4.444	7.52	3.08	9831		
5	10.98	———	4.201	4.281	7.82	3.54	10891		
6		———		4.827	6.69	1.86			

Run number 155 DM Shot number 298 Date 12/13/90 Time 14:28

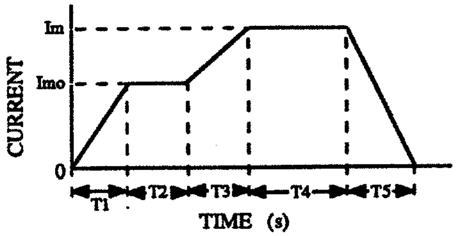
Connection Single coil
Mode AC
Description Two-step trapezoid

Total inlet flow 43.68 g/s
Inlet pressure 5.885 atm
Inlet temperature 4.385 K

Bm 5.670 T
Tm 5.75 s
Bm/Tm 0.986 T/s
1/Tm 0.174 1/s

Im 30 kA
Flat top 3 s
Im/Tm 5.22 kA/s

Waveform



T1 = 2 s
T2 = 3 s
T3 = 0.75 s
T4 = 3 s
T5 = 1 s

Im = 22 kA
Imo = 30 kA

Tm = T1+T2+T3

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
				OUTLET					
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT			
1	11.23	———	4.385	4.413	4.81	0.40			
2		———		4.378	4.88	0.50	1288		4831.5
3 cable	12.49	2.151		4.522	4.93	0.41	376.9	829.3	
3 corner		3.006		4.305	4.75	0.44	452.4		
4 corner		3.422		4.371	4.85	0.48	552.4	942.2	
4 cable		2.362		4.449	4.85	0.40	389.8		
5	19.96	———	4.203	4.281	4.74	0.46	1772		
6		———		4.823	5.18	0.36			

Run number 156 DM Shot number 299 Date 12/13/90 Time 14:42

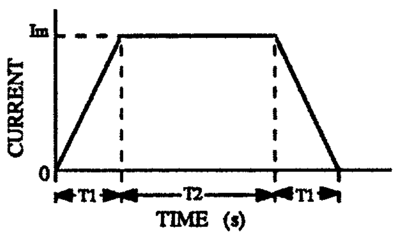
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 35.064 g/s
Inlet pressure 5.106 atm
Inlet temperature 4.375 K

Bm 5.292 T
Tm 4.5 s
Bm/Tm 1.176 T/s
1/Tm 0.222 1/s

Im 28 kA
Flat top 3 s
Im/Tm 6.22 kA/s

Waveform



T1 = 4.5 s
T2 = 3 s
Im = 28 kA
Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
MC03,VB5-6,VB1-2,MC01

Quench time 4.56 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	12.48	—	4.375	4.4	5.04	0.64			
2		—		4.369	5.27	0.90	2800		
3 cable	14.163	2.298		4.51	5.35	0.84	871.3	1829.9	11904.9
3 corner		3		4.296	5.19	0.89	958.6		
4 corner		3.493		4.364	5.49	1.13	1404	2464	
4 cable		2.593		4.441	5.38	0.94	1060		
5	8.421	—	4.194	4.27	6.86	2.59	4811		
6		—		4.812	6.43	1.62			

Run number 157 DM Shot number 300 Date 12/13/90 Time 15:53

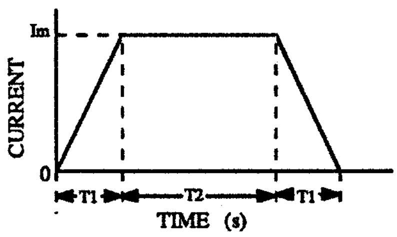
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 41.8 g/s
Inlet pressure 6.002 atm
Inlet temperature 4.375 K

Bm 5.292 T
Tm 6 s
Bm/Tm 0.882 T/s
1/Tm 0.167 1/s

Im 28 kA
Flat top 3 s
Im/Tm 4.67 kA/s

Waveform



T1 = 6 s
T2 = 3 s
Im = 28 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.5	—	4.375	4.407	4.68	0.27			
2		—		4.37	4.70	0.33	803.1		
3 cable	12.17	2.265		4.514	4.79	0.27	257	576	3240.1
3 corner		3.048		4.298	4.59	0.30	319		
4 corner		3.404		4.362	4.68	0.32	378	644	
4 cable		2.423		4.442	4.71	0.27	266		
5	19.13	—	4.196	4.275	4.60	0.33	1217		
6		—		4.818	5.08	0.26			

Run number 158 DM Shot number 301 Date 12/13/90 Time 15:04

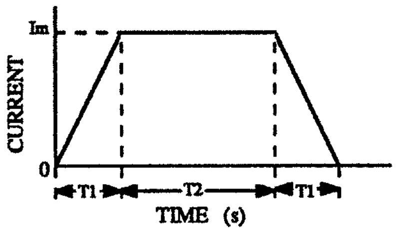
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.95 g/s
Inlet pressure 6.050 atm
Inlet temperature 4.371 K

Bm 5.292 T
Tm 5 s
Bm/Tm 1.058 T/s
1/Tm 0.200 1/s

Im 28 kA
Flat top 3 s
Im/Tm 5.60 kA/s

Waveform



T1 = 5 s
T2 = 3 s
Im = 28 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.9	———	4.371	4.401	4.68	0.28			
2		———		4.364	4.70	0.34	835.4		3267.4
3 cable	12.35	2.222		4.507	4.78	0.28	250	561	
3 corner		2.987		4.292	4.59	0.30	311		
4 corner		3.334		4.358	4.68	0.32	372	629	
4 cable		2.354		4.437	4.71	0.27	257		
5	19.7	———	4.19	4.268	4.60	0.33	1242		
6		———		4.808	5.07	0.26			

Run number 159 DM Shot number 302 Date 12/13/90 Time 15:25

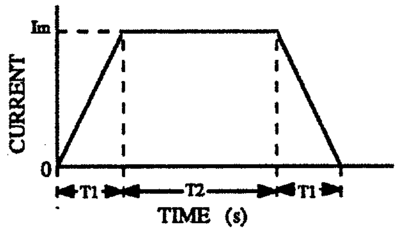
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 38.851 g/s
Inlet pressure 5.239 atm
Inlet temperature 4.368 K

Bm 5.481 T
Tm 6.5 s
Bm/Tm 0.843 T/s
1/Tm 0.154 1/s

Im 29 kA
Flat top 3 s
Im/Tm 4.46 kA/s

Waveform



T1 = 6.5 s
T2 = 3 s
Im = 29 kA
Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6,MC03,MC01

Quench time 6.61 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.207	———	4.368	4.4	5.08	0.68			
2		———		4.358	5.33	0.97	2217		23681
3 cable	11.289	2.529		4.504	5.42	0.91	1043	2160	
3 corner		3.139		4.29	5.26	0.97	1117		
4 corner		3.558		4.352	5.65	1.30	1700	3063	
4 cable		2.829		4.433	5.52	1.09	1363		
5	18.355	———	4.186	4.267	7.80	3.53	16241		
6		———		4.805	6.84	2.04			

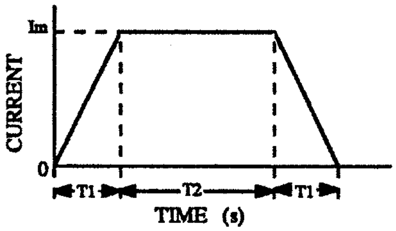
Run number 160 DM Shot number 303 Date 12/13/90 Time 15:36

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 39.394 g/s
Inlet pressure 5.977 atm
Inlet temperature 4.379 K

Bm 5.481 T
Tm 8 s
Bm/Tm 0.685 T/s
1/Tm 0.125 1/s
Im 29 kA
Flat top 3 s
Im/Tm 3.63 kA/s

Waveform



T1 = 8 s
T2 = 3 s

Im = 29 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.504	——	4.379	4.409	4.78	0.37			
2		——		4.372	4.83	0.46	996.5		4267.7
3 cable	11.36	2.448		4.516	4.89	0.37	384.7	820.1	
3 corner		3.138		4.3	4.71	0.41	435.4		
4 corner		3.544		4.367	4.80	0.43	524.8	930.1	
4 cable		2.729		4.443	4.81	0.37	405.3		
5	18.53	——	4.2	4.278	4.70	0.42	1521		
6		——		4.822	5.15	0.33			

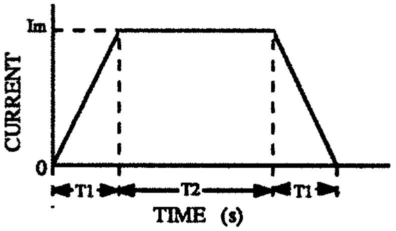
Run number 161 DM Shot number 304 Date 12/13/90 Time 15:46

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 39.025 g/s
Inlet pressure 5.117 atm
Inlet temperature 4.374 K

Bm 5.481 T
Tm 7 s
Bm/Tm 0.783 T/s
1/Tm 0.143 1/s
Im 29 kA
Flat top 3 s
Im/Tm 4.14 kA/s

Waveform



T1 = 7 s
T2 = 3 s

Im = 29 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6,MC03,MC01

Quench time 7.16 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.326	——	4.374	4.398	5.09	0.69			
2		——		4.364	5.34	0.98	2304		24494
3 cable	11.36	2.487		4.509	5.43	0.92	1045	2161	
3 corner		3.079		4.293	5.27	0.98	1116		
4 corner		3.533		4.362	5.66	1.30	1734	3109	
4 cable		2.796		4.432	5.54	1.10	1375		
5	18.339	——	4.193	4.268	7.98	3.71	16920		
6		——		4.806	6.82	2.01			

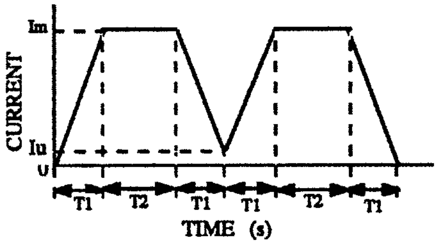
Run number 162 DM Shot number 305 Date 12/13/90 Time 15:57

Connection Single coil
Mode AC
Description Two trapezoid

Total inlet flow 43.42 g/s
Inlet pressure 5.953 atm
Inlet temperature 4.376 K

Bm 2.268 T
Tm .5 s
Bm/Tm 4.536 T/s
1/Tm 2.000 1/s
Im 12 kA
Flat top 3 s
Im/Tm 24.00 kA/s

Waveform



T1 = 0.5 s
T2 = 3 s

Im = 12 kA
Iu = 1 kA

Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.14	———	4.376	4.402	4.69	0.29			
2		———		4.37	4.70	0.33	846		3091.6
3 cable	12.48	2.13		4.514	4.78	0.26	225.2	498.4	
3 corner		2.929		4.299	4.59	0.29	273.2		
4 corner		3.364		4.366	4.68	0.31	337.3	572.2	
4 cable		2.356		4.444	4.70	0.26	234.9		
5	19.8	———	4.198	4.275	4.60	0.32	1175		
6		———		4.822	5.08	0.26			

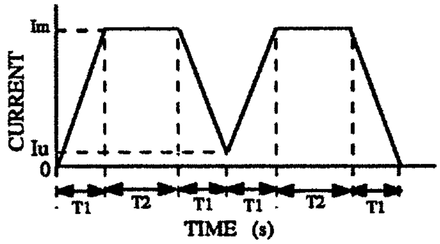
Run number 163 DM Shot number 306 Date 12/13/90 Time 16:08

Connection Single coil
Mode AC
Description Double trapezoid

Total inlet flow 43.18 g/s
Inlet pressure 6.002 atm
Inlet temperature 4.369 K

Bm 3.402 T
Tm .5 s
Bm/Tm 6.804 T/s
1/Tm 2.000 1/s
Im 18 kA
Flat top 3 s
Im/Tm 36.00 kA/s

Waveform



T1 = 0.5 s
T2 = 3 s

Im = 18 kA
Iu = 1 kA

Tm = T1

Quench ? No

Quench time ____ s

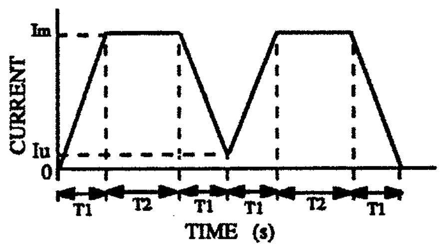
PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.89	———	4.369	4.397	4.85	0.46			
2		———		4.361	4.92	0.56	1483		5533.8
3 cable	12.41	2.18		4.509	4.97	0.46	454.8	947	
3 corner		2.931		4.291	4.79	0.50	492.2		
4 corner		3.383		4.36	4.89	0.53	600.3	1056.8	
4 cable		2.376		4.437	4.88	0.44	456.5		
5	19.88	———	4.189	4.268	4.79	0.52	2047		
6		———		4.808	5.21	0.40			

Run number	164	DM Shot number	307	Date	12/13/90	Time	16:18

Connection	Single coil	Total inlet flow	43.32 g/s
Mode	AC	Inlet pressure	6.026 atm
Description	Double trapezoid	Inlet temperature	4.37 K

Bm	3.780 T	Im	20 kA
Tm	.5 s	Flat top	3 s
Bm/Tm	7.560 T/s	Im/Tm	40.00 kA/s
1/Tm	2.000 1/s		

Waveform



T1 = 0.5 s
T2 = 3 s

Im = 20 kA
Iu = 1 kA

Tm = T1

Quench ? No

Quench time s

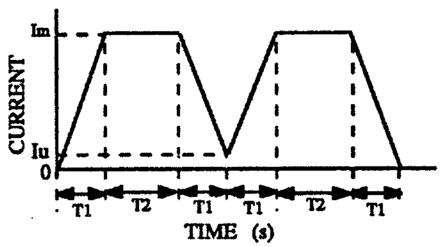
PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.95	—	4.37	4.403	4.92	0.52			
2		—		4.365	5.03	0.66	1857		6865.9
3 cable	12.42	2.326		4.51	5.05	0.54	628.9	1215.9	
3 corner		2.935		4.293	4.88	0.58	587		
4 corner		3.389		4.361	4.99	0.62	724	1337	
4 cable		2.473		4.439	4.96	0.52	613		
5	19.95	—	4.192	4.269	4.87	0.60	2456		
6		—		4.81	5.27	0.46			

Run number	165	DM Shot number	308	Date	12/13/90	Time	16:29

Connection	Single coil	Total inlet flow	40.162 g/s
Mode	AC	Inlet pressure	5.191 atm
Description	Double trapezoid	Inlet temperature	4.375 K

Bm	4.158 T	Im	22 kA
Tm	.5 s	Flat top	3 s
Bm/Tm	8.316 T/s	Im/Tm	44.00 kA/s
1/Tm	2.000 1/s		

Waveform



T1 = 0.5 s
T2 = 3 s

Im = 22 kA
Iu = 1 kA

Tm = T1

Quench ? Yes- Coils B and C initiated from joints.
Quench detection sequence
Quench sequence ?
VB5-6, VB1-2, MC02, MC01

Quench time – s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.209	—	4.375	4.395	5.12	0.73			
2		—		4.363	5.30	0.94	2668		58166.4
3 cable	11.848	2.58		4.502	5.29	0.79	1172	2039.4	
3 corner		2.943		4.295	5.12	0.83	867.4		
4 corner		3.279		4.361	5.25	0.88	1031	2120	
4 cable		2.601		4.44	5.19	0.75	1089		
5	18.105	—	4.195	4.264			51339		
6		—		4.809	5.42	0.61			

Run number 166 DM Shot number 309 Date 12/13/90 Time 16:39

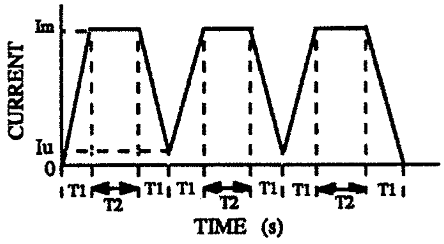
Connection Single coil
Mode AC
Description Triple trapezoid

Total inlet flow 43.35 g/s
Inlet pressure 6.026 atm
Inlet temperature 4.381 K

Bm 2.268 T
Tm .5 s
Bm/Tm 4.536 T/s
1/Tm 2.000 1/s

Im 12 kA
Flat top 3 s
Im/Tm 24.00 kA/s

Waveform



T1 = 0.5 s
T2 = 3 s

Im = 12 kA
Iu = 1 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.82		4.381	4.413	4.79	0.38			
2				4.369	4.83	0.46	1182		2389
3 cable	12.53	2.15		4.517	4.89	0.37	325	724	
3 corner		3		4.3	4.70	0.40	399		
4 corner		3.4		4.369	4.80	0.43	483	483	
4 cable		2.35		X			X		
5	20		4.2	4.283	4.72	0.44	X		
6				4.818	5.17	0.35			

Run number 167 DM Shot number 310 Date 12/13/90 Time 16:50

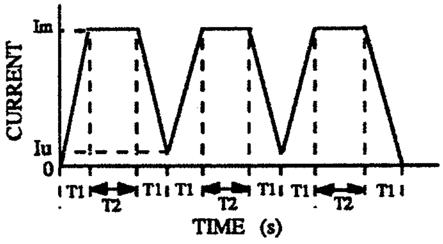
Connection Single coil
Mode AC
Description Triple trapezoid

Total inlet flow 43.5 g/s
Inlet pressure 6.074 atm
Inlet temperature 4.372 K

Bm 3.402 T
Tm .5 s
Bm/Tm 6.804 T/s
1/Tm 2.000 1/s

Im 18 kA
Flat top 3 s
Im/Tm 36.00 kA/s

Waveform



T1 = 0.5 s
T2 = 3 s

Im = 18 kA
Iu = 1 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.9		4.372	4.4	5.03	0.63			
2				4.363	5.16	0.80	2269		8510
3 cable	12.5	2.35		4.509	5.16	0.65	745	1525	
3 corner		3.15		4.294	4.99	0.69	780		
4 corner		3.47		4.362	5.11	0.74	917	1691	
4 cable		2.6		4.438	5.07	0.63	774		
5	20.1		4.192	4.27	5.00	0.73	3025		
6				4.809	5.37	0.56			

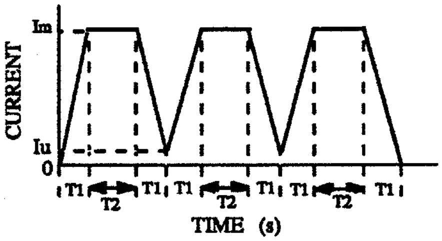
Run number 168 DM Shot number 311 Date 12/13/90 Time 17:00

Connection Single coil
Mode AC
Description Triple trapezoid

Total inlet flow X g/s
Inlet pressure 5.178 atm
Inlet temperature 4.375 K

Bm 3.780 T
Tm .5 s
Bm/Tm 7.560 T/s
1/Tm 2.000 1/s
Im 20 kA
Flat top 3 s
Im/Tm 40.00 kA/s

Waveform



T1 = 0.5 s
T2 = 3 s

Im = 20 kA
Iu = 1 kA

Tm = T1

Quench ? Yes- Coils B and C initiated from joints.

Quench detection sequence
VB5-6, VB3-4,VB1-2,MC02

Quench time – s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]
	INLET	OUTLET	INLET	OUTLET			
				INITIAL	PEAK	ΔT	
1	X	—	4.375	4.405	5.21	0.80	
2		—		4.364	5.39	1.02	X
3 cable	X	X		4.496			X
3 corner		X		4.296	5.20	0.90	X
4 corner		X		4.363	5.32	0.96	X
4 cable		X		4.442	5.26	0.82	X
5	X	—	4.194	4.286			X
6		—		4.816	5.50	0.68	

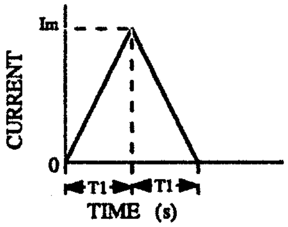
Run number 169 DM Shot number 312 Date 12/14/90 Time 10:07

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow X g/s
Inlet pressure 5.953 atm
Inlet temperature 4.395 K

Bm 0.284 T
Tm 5 s
Bm/Tm 0.057 T/s
1/Tm 0.200 1/s
Im 1.5 kA
Flat top 0 s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s

Im = 1.5 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]
	INLET	OUTLET	INLET	OUTLET			
				INITIAL	PEAK	ΔT	
1	X	—	4.395	4.42			
2		—		4.386			X
3 cable	X	X		4.534			X
3 corner		X		4.319			X
4 corner		X		4.392	4.43	0.04	X
4 cable		X		4.463			X
5	X	—	4.215	4.299			X
6		—		4.845			

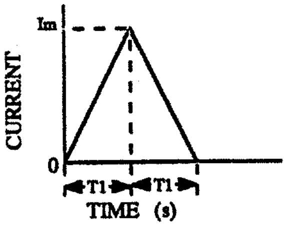
Run number 170 DM Shot number 313 Date 12/14/90 Time 10:14

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow X g/s
Inlet pressure 6.098 atm
Inlet temperature 4.398 K

Bm 0.284 T
Tm 5 s
Bm/Tm 0.057 T/s
1/Tm 0.200 1/s
Im 1.5 kA
Flat top 0 s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s
Im = 1.5 kA
Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]
	INLET	OUTLET	INLET	OUTLET			
				INITIAL	PEAK	ΔT	
1	X	———	4.398	4.426			
2		———		4.39			X
3 cable	X	X		4.539			X
3 corner		X		4.324			X
4 corner		X		4.397			X
4 cable		X		4.468			X
5	X	———	4.219	4.304			X
6		———		4.847			

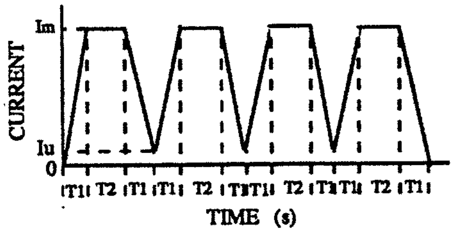
Run number 171 DM Shot number X Date 12/14/90 Time 10:22

Connection Single coil
Mode AC
Description Quadruple trapezoid

Total inlet flow X g/s
Inlet pressure 6.118 atm
Inlet temperature 4.397 K

Bm 2.268 T
Tm .5 s
Bm/Tm 4.536 T/s
1/Tm 2.000 1/s
Im 12 kA
Flat top 2 s
Im/Tm 24.00 kA/s

Waveform



T1 = 0.5 s
T2 = 2 s
Im = 12 kA
Iu = 1 kA
Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]
	INLET	OUTLET	INLET	OUTLET			
				INITIAL	PEAK	ΔT	
1	X	———	4.397	X			
2		———		X			X
3 cable	X	X		X			X
3 corner		X		X			X
4 corner		X		X			X
4 cable		X		X			X
5	X	———	4.218	X			X
6		———		X			

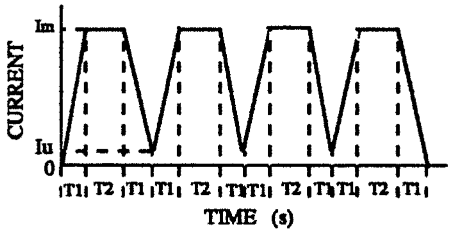
Run number 172 DM Shot number 314 Date 12/14/90 Time 10:28

Connection Single coil
Mode AC
Description Quadruple trapezoid

Total inlet flow 45.3 g/s
Inlet pressure 6.118 atm
Inlet temperature 4.397 K

Bm 2.268 T
Tm .5 s
Bm/Tm 4.536 T/s
1/Tm 2.000 1/s
Im 12 kA
Flat top 2 s
Im/Tm 24.00 kA/s

Waveform



T1 = 0.5 s
T2 = 2 s

Im = 12 kA
Iu = 1 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.8	———	4.397	4.446	4.91	0.46			
2		———		4.387	4.97	0.58	1547		5825
3 cable	13.1	2.23		4.539	5.07	0.53	434	962	
3 corner		3.16		4.323	4.81	0.49	528		
4 corner		3.61		4.396	4.92	0.52	643	1104	
4 cable		2.54		4.468	4.92	0.45	461		
5	21.4	———	4.218	4.302	4.85	0.55	2212		
6		———		4.846	5.29	0.44			

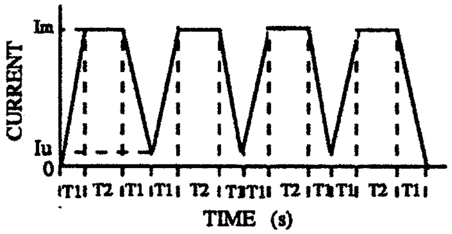
Run number 173 DM Shot number 315 Date 12/14/90 Time 10:39

Connection Single coil
Mode AC
Description Quadruple trapezoid

Total inlet flow X g/s
Inlet pressure 5.178 atm
Inlet temperature 4.398 K

Bm 3.402 T
Tm .5 s
Bm/Tm 6.804 T/s
1/Tm 2.000 1/s
Im 18 kA
Flat top 2 s
Im/Tm 36.00 kA/s

Waveform



T1 = 0.5 s
T2 = 2 s

Im = 18 kA
Iu = 1 kA

Tm = T1

Quench ? ? All most OK, but Coil C initiated from joint.

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X	———	4.398	4.426	5.21	0.78			
2		———		4.389	5.38	0.99	X		
3 cable	X	X		4.538	5.36	0.82	X		
3 corner		X		4.324	5.18	0.86	X		
4 corner		X		4.397	5.32	0.92	X		
4 cable		X		4.468	5.25	0.78	X		
5	X	———	4.219	4.301	5.20	0.90	X		
6		———		4.842	5.54	0.70			

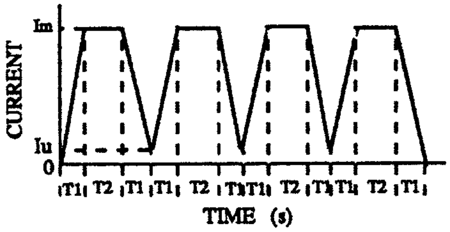
Run number 174 DM Shot number 316 Date 12/14/90 Time 10:51

Connection Single coil
Mode AC
Description Quadruple trapezoid

Total inlet flow 44.65 g/s
Inlet pressure 6.142 atm
Inlet temperature 4.402 K

Bm 3.402 T
Tm 1.75 s
Bm/Tm 1.944 T/s
1/Tm 0.571 1/s
Im 18 kA
Flat top 0.5 s
Im/Tm 10.29 kA/s

Waveform



T1 = 1.75 s
T2 = 0.5 s

Im = 18 kA
Iu = 1 kA

Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.7		4.402	4.43	5.01	0.58			
2				4.392	5.13	0.74	2118		8110
3 cable	12.95	2.25		4.543	5.16	0.61	632	1371	
3 corner		3.1		4.328	4.98	0.65	739		
4 corner		3.59		4.397	5.10	0.70	916	1558	
4 cable		2.44		4.472	5.06	0.59	642		
5	21		4.223	4.307	5.02	0.71	3063		
6				4.846	5.41	0.56			

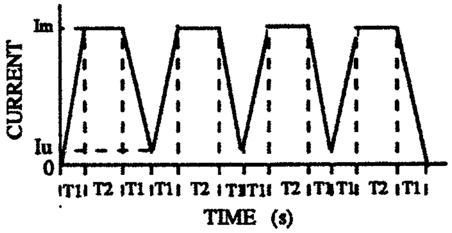
Run number 175 DM Shot number 341 Date 12/14/90 Time 11:05

Connection Single coil
Mode AC
Description Quadruple trapezoid

Total inlet flow 44.4 g/s
Inlet pressure 6.166 atm
Inlet temperature 4.401 K

Bm 3.780 T
Tm 1.75 s
Bm/Tm 2.160 T/s
1/Tm 0.571 1/s
Im 20 kA
Flat top 0.5 s
Im/Tm 11.43 kA/s

Waveform



T1 = 1.75 s
T2 = 0.5 s

Im = 20 kA
Iu = 1 kA

Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.6		4.401	4.427	5.10	0.67			
2				4.389	5.22	0.83	2459		9507
3 cable	12.9	2.25		4.539	5.23	0.69	763	1647	
3 corner		3.2		4.325	5.06	0.73	884		
4 corner		3.62		4.396	5.19	0.79	1064	1892	
4 cable		2.6		4.47	5.14	0.67	828		
5	20.9		4.222	4.304	5.10	0.79	3509		
6				4.844	5.47	0.62			

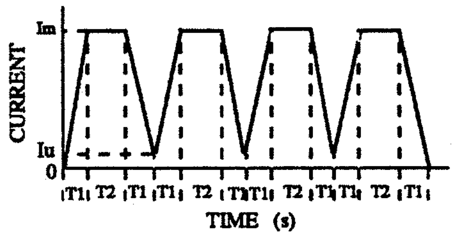
Run number 176 DM Shot number 342 Date 12/14/90 Time 11:16

Connection Single coil
Mode AC
Description Quadruple trapezoid

Total inlet flow 44.65 g/s
Inlet pressure 6.166 atm
Inlet temperature 4.403 K

Bm 4.158 T
Tm 1.75 s
Bm/Tm 2.376 T/s
1/Tm 0.571 1/s
Im 22 kA
Flat top 0.5 s
Im/Tm 12.57 kA/s

Waveform



T1 = 1.75 s
T2 = 0.5 s
Im = 22 kA
Iu = 1 kA
Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.7	—	4.403	4.426	5.17	0.74			
2		—		4.392	5.33	0.93	2939		11192
3 cable	12.95	2.25		4.54	5.32	0.78	935	1948	
3 corner		3.2		4.327	5.15	0.82	1013		
4 corner		3.61		4.398	5.28	0.88	1216	2218	
4 cable		2.58		4.471	5.22	0.75	1002		
5	21	—	4.225	4.306	5.18	0.88	4087		
6		—		4.842	5.53	0.69			

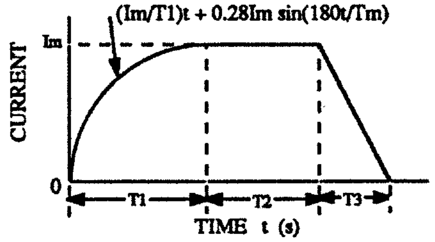
Run number 177 DM Shot number 321 Date 12/14/90 Time 11:27

Connection Single coil
Mode AC
Description Round-edged pulse

Total inlet flow 45.09 g/s
Inlet pressure 6.118 atm
Inlet temperature 4.402 K

Bm 3.780 T
Tm 2.8 s
Bm/Tm 1.350 T/s
1/Tm 0.357 1/s
Im 20 kA
Flat top 3 s
Im/Tm 7.14 kA/s

Waveform



T1 = 2.8 s
T2 = 3 s
T3 = 0.5 s
Im = 20 kA
Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.83	—	4.402	4.431	4.71	0.27			
2		—		4.392	4.73	0.33	840.6		3158.8
3 cable	13.05	2.264		4.543	4.81	0.27	245.3	541.5	
3 corner		3.163		4.327	4.61	0.29	296.2		
4 corner		3.569		4.398	4.71	0.31	354.9	614.7	
4 cable		2.57		4.473	4.73	0.26	259.8		
5	21.21	—	4.223	4.307	4.61	0.30	1162		
6		—		4.844	5.09	0.24			

Run number 178 DM Shot number 322 Date 12/14/90 Time 11:37

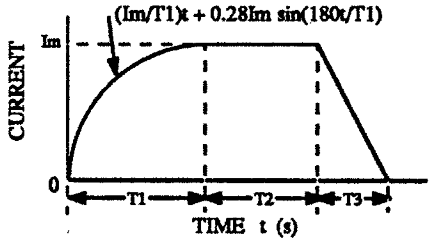
Connection Single coil
Mode AC
Description Round-edged pulse

Total inlet flow 45.12 g/s
Inlet pressure 6.166 atm
Inlet temperature 4.398 K

Bm 4.725 T
Tm 3.5 s
Bm/Tm 1.350 T/s
1/Tm 0.286 1/s

Im 25 kA
Flat top 3 s
Im/Tm 7.14 kA/s

Waveform



T1 = 3.5 s
T2 = 3 s
T3 = 0.5 s

Im = 25 kA

Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.84	—	4.398	4.421	4.78	0.36			
2		—		4.389	4.85	0.46	1157		4289.8
3 cable	13.1	2.22		4.537	4.91	0.37	336.9	737.8	
3 corner		3.141		4.324	4.72	0.39	400.9		
4 corner		3.584		4.395	4.82	0.42	484.7	840	
4 cable		2.542		4.467	4.82	0.35	355.3		
5	21.18	—	4.218	4.303	4.70	0.40	1555		
6		—		4.837	5.15	0.31			

Run number 179 DM Shot number 323 Date 12/14/90 Time 11:47

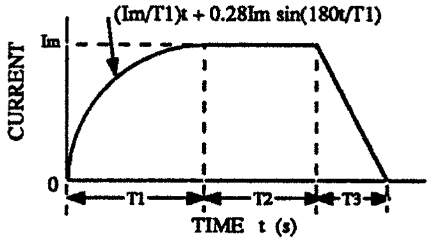
Connection Single coil
Mode AC
Description Round-edged pulse

Total inlet flow 45.35 g/s
Inlet pressure 6.166 atm
Inlet temperature 4.398 K

Bm 5.292 T
Tm 3.9 s
Bm/Tm 1.357 T/s
1/Tm 0.256 1/s

Im 28 kA
Flat top 3 s
Im/Tm 7.18 kA/s

Waveform



T1 = 3.9 s
T2 = 3 s
T3 = 0.5 s

Im = 28 kA

Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.93	—	4.398	4.428	4.85	0.43			
2		—		4.39	4.94	0.55	1425		2948.9
3 cable	13.13	2.308		4.54	4.99	0.45	438.8	936	
3 corner		3.203		4.325	4.80	0.47	497.2		
4 corner		3.584		4.397	4.91	0.51	587.9	587.9	
4 cable		2.598		4.47	4.89	0.42	X		
5	21.29	—	4.221	4.306	4.78	0.48	X		
6		—		4.842	5.20	0.36			

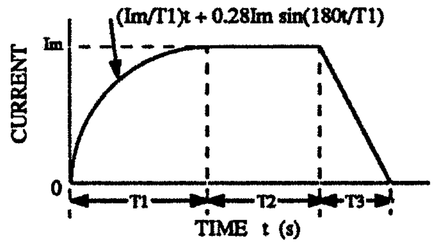
Run number 180 DM Shot number 324 Date 12/14/90 Time 13:18

Connection Single coil
Mode AC
Description Round-edged pulse

Total inlet flow 45.2 g/s
Inlet pressure 6.190 atm
Inlet temperature 4.396 K

Bm 5.670 T
Im 30 kA
Tm 4.2 s
Flat top s
Bm/Tm 1.350 T/s
Im/Tm 7.14 kA/s
1/Tm 0.238 1/s

Waveform



T1 = 4.2 s
T2 = 3 s
T3 = 0.5 s

Im = 30 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.03	———	4.396	4.414	4.89	0.48			
2		———		4.385	4.99	0.61	1593		5835.7
3 cable	13.08	2.33		4.534	5.04	0.51	499.9	1024.2	
3 corner		3.179		4.322	4.85	0.53	524.3		
4 corner		3.584		4.394	4.97	0.57	654.2	1156.5	
4 cable		2.581		4.465	4.94	0.48	502.3		
5	21.09	———	4.217	4.301	4.83	0.53	2062		
6		———		4.831	5.24	0.41			

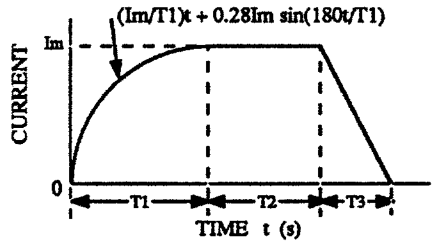
Run number 181 DM Shot number 325 Date 12/14/90 Time 13:29

Connection Single coil
Mode AC
Description Round-edged pulse

Total inlet flow 35.74 g/s
Inlet pressure 5.206 atm
Inlet temperature 4.395 K

Bm 5.670 T
Im 30 kA
Tm 2.8 s
Flat top 3 s
Bm/Tm 2.025 T/s
Im/Tm 10.71 kA/s
1/Tm 0.357 1/s

Waveform



T1 = 2.8 s
T2 = 3 s
T3 = 0.5 s

Im = 30 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
MC03, VB5-6,MC01

Quench time 1.78 s

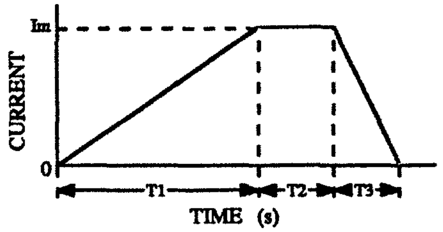
PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	12.426	———	4.395	4.424	5.10	0.68			
2		———		4.386	5.34	0.96	3046		12783
3 cable	14.608	2.511		4.533	5.42	0.89	1020	2093	
3 corner		3.261		4.32	5.25	0.93	1073		
4 corner		3.705		4.393	5.57	1.18	1514	2744	
4 cable		2.842		4.466	5.45	0.98	1230		
5	8.706	———	4.217	4.3	6.94	2.64	4900		
6		———		4.835	6.47	1.64			

Run number 182 DM Shot number 326 Date 12/14/90 Time 13:39

Connection Single coil
Mode AC
Description Slow-ramp trapezoid
Total inlet flow 40.49 g/s
Inlet pressure 5.208 atm
Inlet temperature 4.402 K

Bm 5.576 T
Tm 8 s
Bm/Tm 0.697 T/s
1/Tm 0.125 1/s
Im 29.5 kA
Flat top 3 s
Im/Tm 3.69 kA/s

Waveform



T1 = 8 s
T2 = 3 s
T3 = 1 s

Im = 29.5 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6,MC03,MC01

Quench time 7.98 s

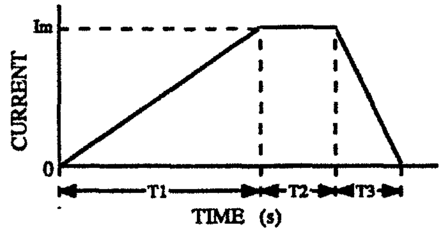
PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.046	—	4.402	4.426	5.12	0.70			
2		—		4.394	5.36	0.97	2260		18931
3 cable	11.998	2.627		4.541	5.44	0.90	1057	2170	
3 corner		3.248		4.327	5.28	0.95	1113		
4 corner		3.691		4.4	5.60	1.20	1578	2860	
4 cable		2.956		4.471	5.48	1.01	1282		
5	19.446	—	4.223	4.311	7.04	2.73	11641		
6		—		4.846	6.51	1.66			

Run number 183 DM Shot number 343 Date 12/14/90 Time 13:50

Connection Single coil
Mode AC
Description Slow-ramp trapezoid
Total inlet flow 41.801 g/s
Inlet pressure 6.074 atm
Inlet temperature 4.404 K

Bm 5.765 T
Tm 10 s
Bm/Tm 0.577 T/s
1/Tm 0.100 1/s
Im 30.5 kA
Flat top 3 s
Im/Tm 3.05 kA/s

Waveform



T1 = 10 s
T2 = 3 s
T3 = 1 s

Im = 30.5 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.551	—	4.404	4.434	4.83	0.39			
2		—		4.397	4.90	0.50	1129		4733.3
3 cable	12.18	2.485		4.546	4.95	0.40	415.5	889.8	
3 corner		3.253		4.331	4.76	0.43	474.3		
4 corner		3.694		4.402	4.87	0.47	574.5	1020.5	
4 cable		2.838		4.475	4.87	0.39	446		
5	20.07	—	4.228	4.311	4.76	0.45	1694		
6		—		4.851	5.20	0.35			

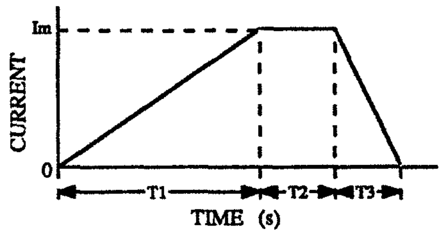
Run number 184 DM Shot number 344 Date 12/14/90 Time 14:00

Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 41.28 g/s
Inlet pressure 6.118 atm
Inlet temperature 4.402 K

Bm 5.765 T
Im 30.5 kA
Tm 9 s
Flat top 3 s
Bm/Tm 0.641 T/s
Im/Tm 3.39 kA/s
1/Tm 0.111 1/s

Waveform



T1 = 9 s
T2 = 3 s
T3 = 1 s

Im = 30.5 kA

Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.36	—	4.402	4.42	4.82	0.40			
2		—		4.391	4.89	0.50	1126		4680.7
3 cable	12.01	2.509		4.539	4.94	0.40	416.7	894.2	
3 corner		3.293		4.326	4.76	0.43	477.5		
4 corner		3.71		4.397	4.87	0.47	566.8	1014.5	
4 cable		2.87		4.47	4.86	0.39	447.7		
5	19.91	—	4.223	4.305	4.75	0.45	1646		
6		—		4.838	5.19	0.35			

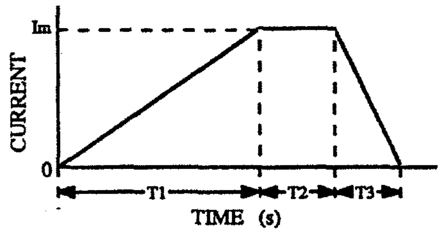
Run number 185 DM Shot number 327 Date 12/14/90 Time 14:11

Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 40.297 g/s
Inlet pressure 6.142 atm
Inlet temperature 4.397 K

Bm 5.765 T
Im 30.5 kA
Tm 8 s
Flat top 3 s
Bm/Tm 0.721 T/s
Im/Tm 3.81 kA/s
1/Tm 0.125 1/s

Waveform



T1 = 8 s
T2 = 3 s
T3 = 1 s

Im = 30.5 kA

Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	8.667	—	4.397	4.422	4.82	0.40			
2		—		4.384	4.89	0.51	1044		4606.5
3 cable	11.96	2.511		4.537	4.94	0.40	417.3	898.5	
3 corner		3.311		4.323	4.76	0.44	481.2		
4 corner		3.76		4.395	4.87	0.47	578.7	1032	
4 cable		2.906		4.467	4.86	0.39	453.3		
5	19.67	—	4.217	4.301	4.75	0.45	1632		
6		—		4.838	5.19	0.35			

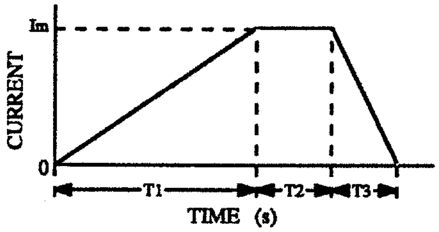
Run number 186 DM Shot number 328 Date 12/14/90 Time 14:22

Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 40.189 g/s
Inlet pressure 5.215 atm
Inlet temperature 4.397 K

Bm 5.765 T Im 30.5 kA
Tm 7.5 s Flat top 3 s
Bm/Tm 0.769 T/s Im/Tm 4.07 kA/s
1/Tm 0.133 1/s

Waveform



T1 = 7.5 s
T2 = 3 s
T3 = 1 s

Im = 30.5 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6, MC03, VB3-4,MC01

Quench time 7.22 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	8.668	———	4.397	4.422	5.15	0.73			
2		———		4.386	5.43	1.04	2394		30043
3 cable	12.109	2.474		4.537	5.54	1.00	1121	2335	
3 corner		3.118		4.324	5.38	1.06	1214		
4 corner		3.654		4.399	5.83	1.43	1981	3571	
4 cable		2.908		4.454	5.69	1.24	1590		
5	19.412	———	4.218	4.3	8.95	4.65	21743		
6		———		4.839	7.20	2.36			

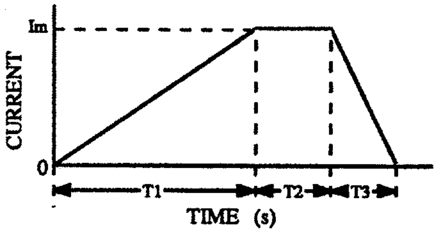
Run number 187 DM Shot number 329 Date 12/14/90 Time 14:32

Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 40.843 g/s
Inlet pressure 6.074 atm
Inlet temperature 4.41 K

Bm 5.576 T Im 29.5 kA
Tm 9 s Flat top 3 s
Bm/Tm 0.620 T/s Im/Tm 3.28 kA/s
1/Tm 0.111 1/s

Waveform



T1 = 9 s
T2 = 3 s
T3 = 1 s

Im = 29.5 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	8.933	———	4.41	4.425	4.79	0.37			
2		———		4.393	4.86	0.47	1000		4324
3 cable	12.05	2.528		4.545	4.92	0.38	387.8	835.4	
3 corner		3.313		4.333	4.74	0.41	447.6		
4 corner		3.723		4.404	4.84	0.44	530.5	944.6	
4 cable		2.869		4.476	4.84	0.37	414.1		
5	19.86	———	4.232	4.313	4.73	0.42	1544		
6		———		4.853	5.18	0.32			

Run number 188 DM Shot number 330 Date 12/14/90 Time 14:43

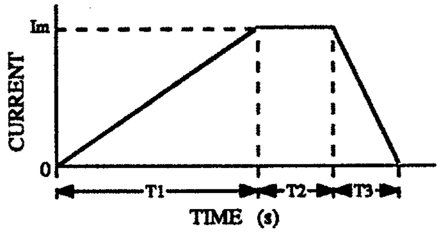
Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 40.607 g/s
Inlet pressure 6.098 atm
Inlet temperature 4.395 K

Bm 5.859 T
Tm 9 s
Bm/Tm 0.651 T/s
1/Tm 0.111 1/s

Im 31 kA
Flat top 3 s
Im/Tm 3.44 kA/s

Waveform



T1 = 9 s
T2 = 3 s
T3 = 1 s

Im = 31 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	8.847	—	4.395	4.42	4.83	0.41			
2		—		4.385	4.91	0.52	1123		4821.1
3 cable	12	2.469		4.536	4.96	0.42	431.9	929.1	
3 corner		3.244		4.323	4.78	0.45	497.2		
4 corner		3.722		4.392	4.88	0.49	595.3	1064	
4 cable		2.855		4.468	4.88	0.41	468.7		
5	19.76	—	4.216	4.302	4.76	0.46	1705		
6		—		4.84	5.20	0.36			

Run number 189 DM Shot number 331 Date 12/14/90 Time 14:54

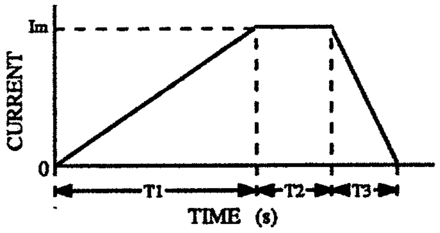
Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 40.348 g/s
Inlet pressure 5.302 atm
Inlet temperature 4.396 K

Bm 5.859 T
Tm 8 s
Bm/Tm 0.732 T/s
1/Tm 0.125 1/s

Im 31 kA
Flat top 3 s
Im/Tm 3.88 kA/s

Waveform



T1 = 8 s
T2 = 3 s
T3 = 1 s

Im = 31 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6, MC03, VB3-4,VB1-2

Quench time 7.58 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	8.672	—	4.396	4.417	5.16	0.75			
2		—		4.386	5.44	1.05	2401		29416
3 cable	12.147	2.505		4.536	5.56	1.02	1147	2386	
3 corner		3.148		4.325	5.40	1.08	1239		
4 corner		3.68		4.399	5.84	1.44	1995	3575	
4 cable		2.911		4.454	5.68	1.23	1580		
5	19.529	—	4.217	4.299	8.82	4.52	21054		
6		—		4.835	7.22	2.39			

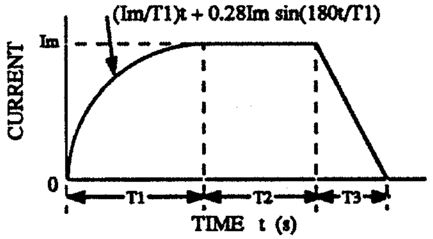
Run number 190 DM Shot number 332 Date 12/14/90 Time 15:25

Connection Single coil
Mode AC
Description Round-edged pulse

Total inlet flow 42.635 g/s
Inlet pressure 5.552 atm
Inlet temperature 4.379 K

Bm 6.237 T
Im 33 kA
Tm 12 s
Flat top 1 s
Bm/Tm 0.520 T/s
Im/Tm 2.75 kA/s
1/Tm 0.083 1/s

Waveform



T1 = 12 s
T2 = 1 s
T3 = 1 s

Im = 33 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.535	———	4.379	4.4	4.86	0.46			
2		———		4.366	4.94	0.57	1312		5553.3
3 cable	12.58	2.638		4.517	4.98	0.46	511.3	1081.9	
3 corner		3.464		4.304	4.79	0.49	570.6		
4 corner		3.83		4.375	4.90	0.53	669.3	1199.4	
4 cable		2.943		4.449	4.89	0.44	530.1		
5	20.52	———	4.199	4.281	4.79	0.51	1960		
6		———		4.818	5.23	0.41			

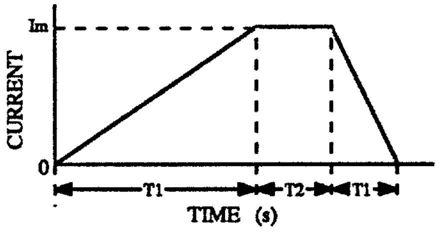
Run number 191 DM Shot number 333 Date 12/14/90 Time 15:36

Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 14.117 g/s
Inlet pressure 4.368 atm
Inlet temperature 4.387 K

Bm 6.048 T
Im 32 kA
Tm 9 s
Flat top 3 s
Bm/Tm 0.672 T/s
Im/Tm 3.56 kA/s
1/Tm 0.111 1/s

Waveform



T1 = 9 s
T2 = 3 s

Im = 1 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6,MC03,VB3-4,VB1-2

Quench time 8.26 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	2.723	———	4.387	4.404	5.14	0.74			
2		———		4.373	5.40	1.03	709.8		10637.7
3 cable	3.13	.727		4.525	5.51	0.99	314.5	616.4	
3 corner		.816		4.312	5.34	1.03	301.9		
4 corner		.858		4.385	5.75	1.37	438.4	831.5	
4 cable		.764		4.457	5.61	1.15	393.1		
5	8.264	———	4.209	4.29	8.80	4.51	8480		
6		———		4.826	7.00	2.17			

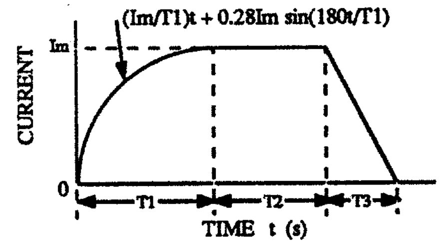
Run number 192 DM Shot number 334 Date 12/14/90 Time 15:49

Connection Single coil
Mode AC
Description Round-edged pulse

Total inlet flow 44.69 g/s
Inlet pressure 5.247 atm
Inlet temperature 4.397 K

Bm 6.426 T Im 34 kA
Tm 14 s Flat top 1 s
Bm/Tm 0.459 T/s Im/Tm 2.43 kA/s
1/Tm 0.071 1/s

Waveform



T1 = 14 s
T2 = 1 s
T3 = 1 s

Im = 34 kA

Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.24	—	4.397	4.418	4.90	0.48			
2		—		4.389	4.98	0.59	1506		5987.3
3 cable	13.16	2.513		4.538	5.01	0.47	524.8	1106.5	
3 corner		3.346		4.325	4.83	0.50	581.7		
4 corner		3.749		4.397	4.94	0.54	695.4	1248.8	
4 cable		2.855		4.471	4.93	0.46	553.4		
5	21.29	—	4.216	4.304	4.82	0.52	2126		
6		—		4.84	5.26	0.42			

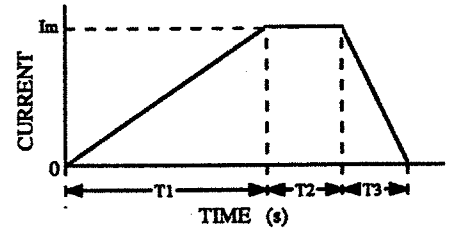
Run number 193 DM Shot number 335 Date 12/14/90 Time 15:59

Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 38.591 g/s
Inlet pressure 4.605 atm
Inlet temperature 4.401 K

Bm 6.237 T Im 33 kA
Tm 10 s Flat top 3 s
Bm/Tm 0.624 T/s Im/Tm 3.30 kA/s
1/Tm 0.100 1/s

Waveform



T1 = 10 s
T2 = 3 s
T3 = 2 s

Im = 33 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6,VB3-4,MC03,MC02,MC01

Quench time 9.95 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	8.42	—	4.401	4.429	5.40	0.97			
2		—		4.384	6.50	2.12	5830		64419
3 cable	11.376	2.48		4.533	7.80	3.27	6854	18850	
3 corner		3.196		4.318	9.90	5.58	11996		
4 corner		3.527		4.39	10.60	6.21	12932	21020	
4 cable		2.744		4.468	7.75	3.28	8088		
5	18.795	—	4.223	4.29	8.27	3.98	18719		
6		—		4.84	6.79	1.95			

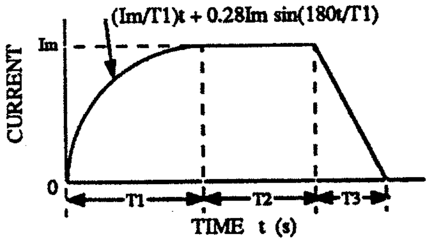
Run number 194 DM Shot number 336 Date 12/14/90 Time 16:10

Connection Single coil
Mode AC
Description Round-edged pulse

Total inlet flow 39.385 g/s
Inlet pressure 5.527 atm
Inlet temperature 4.408 K

Bm 6.615 T
Tm 14 s
Bm/Tm 0.473 T/s
1/Tm 0.071 1/s
Im 35 kA
Flat top 1 s
Im/Tm 2.50 kA/s

Waveform



T1 = 14 s
T2 = 1 s
T3 = 1 s

Im = 35 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	8.245	—	4.408	4.429	4.92	0.49			
2		—		4.381	5.02	0.64	1489		6230.8
3 cable	11.92	2.377		4.542	5.06	0.52	591	1217.5	
3 corner		3.066		4.323	4.88	0.56	626.5		
4 corner		3.431		4.393	4.99	0.60	741.4	1313.3	
4 cable		2.594		4.484	4.98	0.50	571.9		
5	19.22	—	4.23	4.3	4.87	0.57	2211		
6		—		4.843	5.28	0.44			

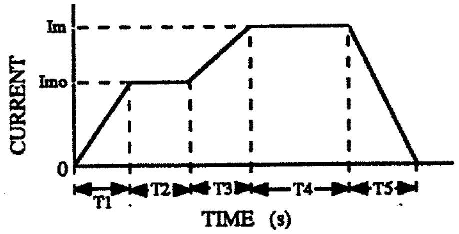
Run number 195 DM Shot number 337 Date 12/14/90 Time 16:22

Connection Single coil
Mode AC
Description Two-step trapezoid

Total inlet flow 41.601 g/s
Inlet pressure 5.673 atm
Inlet temperature 4.39 K

Bm 4.725 T
Tm 5 s
Bm/Tm 0.945 T/s
1/Tm 0.200 1/s
Im 25 kA
Flat top 3 s
Im/Tm 5.00 kA/s

Waveform



T1 = 4 s
T2 = 3 s
T3 = 1 s
T4 = 3 s
T5 = 5 s

Im = 25 kA
Imo = 20 kA

Tm = T1+T2+T3

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.591	—	4.39	4.403	4.64	0.24			
2		—		4.375	4.67	0.29	773		3114
3 cable	12.29	2.482		4.518	4.76	0.24	264	579	
3 corner		3.222		4.305	4.57	0.27	315		
4 corner		3.504		4.374	4.66	0.29	363	625	
4 cable		2.548		4.463	4.70	0.24	262		
5	19.72	—	4.211	4.27	4.57	0.30	1137		
6		—		4.823	5.05	0.23			

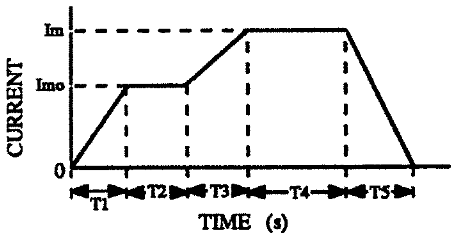
Run number 196 DM Shot number 338 Date 12/14/90 Time 16:33

Connection Single coil
Mode AC
Description Two-step trapezoid

Total inlet flow 41.498 g/s
Inlet pressure 5.740 atm
Inlet temperature 4.385 K

Bm 4.725 T
Tm 2 s
Bm/Tm 2.363 T/s
1/Tm 0.500 1/s
Im 25 kA
Flat top 3 s
Im/Tm 12.50 kA/s

Waveform



T1 = 1.6 s
T2 = 3 s
T3 = 0.4 s
T4 = 3 s
T5 = 2 s

Im = 25 kA
Imo = 20 kA

Tm = T1+T2+T3

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT			
1	9.538	———	4.385	4.396	4.68	0.28			
2		———		4.358	4.72	0.36	894.1		3424.1
3 cable	12.27	2.176		4.511	4.80	0.29	266	595	
3 corner		2.976		4.3	4.61	0.31	329		
4 corner		3.351		4.369	4.71	0.34	393	669	
4 cable		2.371		4.459	4.74	0.28	276		
5	19.69	———	4.207	4.275	4.61	0.33	1266		
6		———		4.813	5.08	0.26			

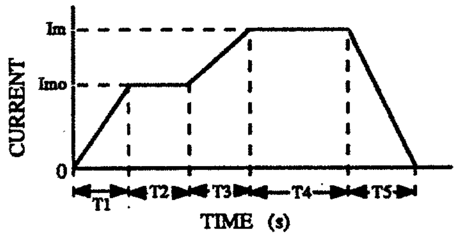
Run number 197 DM Shot number 339 Date 12/14/90 Time 16:43

Connection Single coil
Mode AC
Description Two-step trapezoid

Total inlet flow 41.587 g/s
Inlet pressure 5.764 atm
Inlet temperature 4.385 K

Bm 4.725 T
Tm .5 s
Bm/Tm 9.450 T/s
1/Tm 2.000 1/s
Im 25 kA
Flat top 3 s
Im/Tm 50.00 kA/s

Waveform



T1 = 0.8 s
T2 = 3 s
T3 = 0.2 s
T4 = 3 s
T5 = 1 s

Im = 25 kA
Imo = 20 kA

Tm = T1+T2+T3

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT			
1	9.567	———	4.385	4.394	4.74	0.34			
2		———		4.355	4.79	0.44	1096		4107
3 cable	12.24	2.162		4.511	4.86	0.35	328	717	
3 corner		2.988		4.3	4.68	0.38	389		
4 corner		3.345		4.368	4.78	0.41	462	803	
4 cable		2.388		4.459	4.80	0.34	341		
5	19.78	———	4.206	4.274	4.66	0.39	1491		
6		———		4.816	5.11	0.30			

Run number 198 DM Shot number 340 Date 12/14/90 Time 16:54

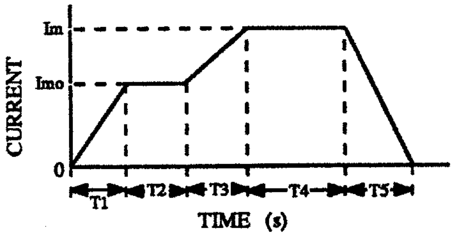
Connection Single coil
Mode AC
Description Two-step trapezoid

Total inlet flow 41.792 g/s
Inlet pressure 5.789 atm
Inlet temperature 4.386 K

Bm 4.725 T
Tm 3.5 s
Bm/Tm 1.350 T/s
1/Tm 0.286 1/s

Im 25 kA
Flat top 3 s
Im/Tm 7.14 kA/s

Waveform



T1 = 0.4 s
T2 = 3 s
T3 = 0.1 s
T4 = 3 s
T5 = 0.5 s

Im = 25 kA
Imo = 20 kA

Tm = T1+T2+T3

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.612	———	4.386	4.393	4.81	0.41			
2		———		4.355	4.90	0.55		1422	5230
3 cable	12.39	2.25		4.511	4.95	0.44	467	947	
3 corner		2.969		4.3	4.77	0.47	480		
4 corner		3.347		4.369	4.88	0.51	573	1036	
4 cable		2.428		4.459	4.88	0.42	463		
5	19.79	———	4.207	4.277	4.75	0.47		1825	
6		———		4.81	5.16	0.35			

Run number 199 DM Shot number 29 Date 12/17/90 Time 10:05

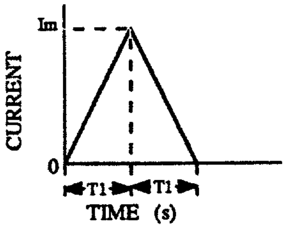
Connection Single coil
Mode AC
Description Single triangle

Total inlet flow X g/s
Inlet pressure 2.812 atm
Inlet temperature 4.357 K

Bm 0.284 T
Tm 5 s
Bm/Tm 0.057 T/s
1/Tm 0.200 1/s

Im 1.5 kA
Flat top 0 s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s

Im = 1.5 kA

Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X	———	4.357	X	4.34	4.34			
2		———		X				X	
3 cable	X	X		X			X		
3 corner		X		X			X		
4 corner		X		X			X		
4 cable		X		X			X		
5	X	———	4.177	X				X	
6		———		X	5.27	5.27			

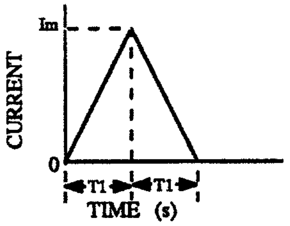
Run number 200 DM Shot number 30 Date 12/17/90 Time 10:15

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow 45 g/s
Inlet pressure 2.763 atm
Inlet temperature 4.365 K

Bm 0.284 T
Tm 5 s
Bm/Tm 0.057 T/s
1/Tm 0.200 1/s
Im 1.5 kA
Flat top s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s
Im = 1.5 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1		—	4.365	x	4.349	4.349			
2		—		x	4.307	4.307			
3 cable				x					
3 corner				x					
4 corner				x	4.342	4.342			
4 cable				x					
5		—	4.185	x	4.237	4.237			
6		—		x					

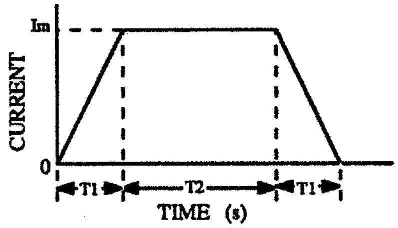
Run number 201 DM Shot number 31 Date 12/17/90 Time 10:24

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 49.87 g/s
Inlet pressure 1.852 atm
Inlet temperature 4.357 K

Bm 4.347 T
Tm 1 s
Bm/Tm 4.347 T/s
1/Tm 1.000 1/s
Im 23 kA
Flat top 3 s
Im/Tm 23.00 kA/s

Waveform



T1 = 1 s
T2 = 3 s

Im = 23 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
MC03, VB3-4, MC01

Quench time 1.09 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.32	—	4.357	4.342	4.771	0.429			
2		—		4.301	4.850	0.549	2082		9066.4
3 cable	14.26	2.3		4.453	4.927	0.474	768.7	1441.9	
3 corner		3		4.237	4.736	0.499	673.2		
4 corner		3.05		4.304	4.860	0.556	792.3	1461.5	
4 cable		2.35		4.396	4.862	0.466	669.2		
5	25.29	—	4.177	4.209	4.905	0.696	4081		
6		—		4.763	5.217	0.454			

Run number 202 DM Shot number 32 Date 12/17/90 Time 10:36

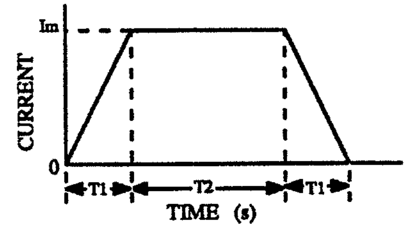
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 43.358 g/s
Inlet pressure 2.763 atm
Inlet temperature 4.361 K

Bm 4.158 T
Tm 1 s
Bm/Tm 4.158 T/s
1/Tm 1.000 1/s

Im 22 kA
Flat top 3 s
Im/Tm 22.00 kA/s

Waveform



T1 = 1 s
T2 = 3 s

Im = 22 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.648	—	4.361	4.347	4.605	0.258			
2		—		4.3	4.607	0.307	987.4		3762.3
3 cable	12.83	2.331		4.454	4.698	0.244	347.8	702.8	
3 corner		3.227		4.238	4.500	0.262	355		
4 corner		3.338		4.305	4.587	0.282	402	718.1	
4 cable		2.434		4.398	4.634	0.236	316.1		
5	20.88	—	4.181	4.211	4.488	0.277	1354		
6		—		4.765	4.992	0.227			

Run number 203 DM Shot number 33 Date 12/17/90 Time 10:46

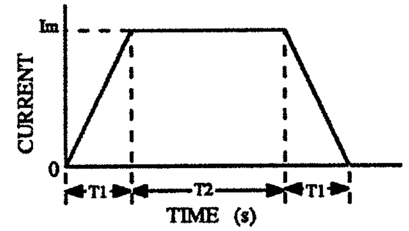
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 41.85 g/s
Inlet pressure 1.858 atm
Inlet temperature 4.357 K

Bm 4.347 T
Tm 1 s
Bm/Tm 4.347 T/s
1/Tm 1.000 1/s

Im 23 kA
Flat top 3 s
Im/Tm 23.00 kA/s

Waveform



T1 = 1 s
T2 = 3 s

Im = 23 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
MC03,VB3-4,MC01

Quench time 1.09 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	12.384	—	4.357	4.331	4.772	0.441			
2		—		4.291	4.860	0.569	2623		9306.5
3 cable	16.614	2.288		4.45	4.950	0.500	808.7	1543.9	
3 corner		3.063		4.233	4.757	0.524	735.2		
4 corner		3.167		4.299	4.885	0.586	889.9	1685.6	
4 cable		2.585		4.391	4.890	0.499	795.7		
5	12.852	—	4.177	4.206	4.997	0.791	3454		
6		—		4.758	5.305	0.547			

Run number 204 DM Shot number 34 Date 12/17/90 Time 11:02

Connection Single coil
Mode AC
Description Miss shot

Total inlet flow 42.833 g/s
Inlet pressure 1.897 atm
Inlet temperature 4.355 K

Bm ____ T Im ____ kA
Tm ____ s Flat top ____ s
Bm/Tm ____ T/s Im/Tm ____ kA/s
1/Tm ____ 1/s

Waveform

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.433		4.355	4.348	4.535	0.187			
2				4.298	4.526	0.228	686		2726
3 cable	12.67	2.249		4.45	4.632	0.182	229	489	
3 corner		3.19		4.233	4.430	0.197	260		
4 corner		3.293		4.298	4.511	0.213	293	538	
4 cable		2.662		4.393	4.570	0.177	245		
5	20.73		4.175	4.204	4.417	0.213	1013		
6				4.761	4.932	0.171			

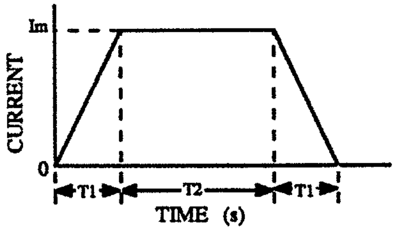
Run number 205 DM Shot number 35 Date 12/17/90 Time 11:24

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 42.991 g/s
Inlet pressure 2.787 atm
Inlet temperature 4.352 K

Bm 3.780 T Im 20 kA
Tm 1 s Flat top 13 s
Bm/Tm 3.780 T/s Im/Tm 20.00 kA/s
1/Tm 1.000 1/s

Waveform



T1 = 1 s
T2 = 13 s

Im = 20 kA

Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.521		4.352	4.332	4.580	0.248			
2				4.292	4.571	0.279	870		3318
3 cable	12.67	2.282		4.447	4.664	0.217	283	596	
3 corner		3.165		4.23	4.464	0.234	313		
4 corner		3.282		4.295	4.549	0.254	355	642	
4 cable		2.655		4.39	4.601	0.211	287		
5	20.8		4.172	4.203	4.452	0.249	1210		
6				4.752	4.965	0.213			

Run number 206 DM Shot number 36 Date 12/17/90 Time 11:35

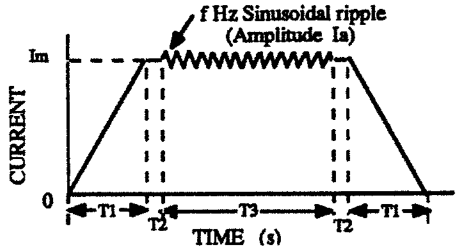
Connection Single coil
Mode AC
Description Trapezoid with ripple on flat top

Total inlet flow 42.65 g/s
Inlet pressure 2.787 atm
Inlet temperature 4.351 K

Bm 3.780 T
Tm 1 s
Bm/Tm 3.780 T/s
1/Tm 1.000 1/s

Im 20 kA
Flat top s
Im/Tm 20.00 kA/s

Waveform



T1 = 1 s
T2 = 1 s
T3 = 11 s

Im = 20 kA
Ia = 300 A

f = 6.5 Hz

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.6	————	4.351	4.338	4.635	0.297			
2		————		4.294	4.650	0.356	1088		4073
3 cable	12.64	2.1		4.448	4.728	0.280	324	718	
3 corner		3.22		4.231	4.532	0.301	394		
4 corner		3.34		4.295	4.622	0.327	449	812	
4 cable		2.62		4.391	4.663	0.272	363		
5	20.41	————	4.168	4.201	4.521	0.320	1455		
6		————		4.755	5.008	0.253			

Run number 207 DM Shot number 37 Date 12/17/90 Time 11:46

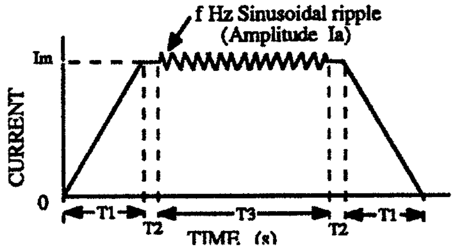
Connection Single coil
Mode AC
Description Trapezoid with ripple on flat top

Total inlet flow 42.75 g/s
Inlet pressure 2.787 atm
Inlet temperature 4.348 K

Bm 3.780 T
Tm 1 s
Bm/Tm 3.780 T/s
1/Tm 1.000 1/s

Im 20 kA
Flat top s
Im/Tm 20.00 kA/s

Waveform



T1 = 1 s
T2 = 1 s
T3 = 11 s

Im = 20 kA
Ia = 700 A

f = 6.5 Hz

Tm = T1

Quench ? No

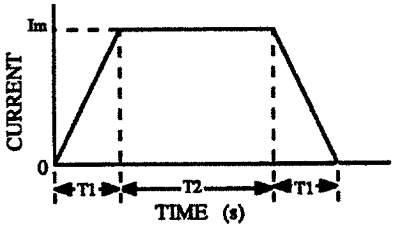
Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.6	————	4.348	4.332	4.905	0.573			
2		————		4.288	4.992	0.704	2534		9566
3 cable	12.7	2.15		4.445	5.025	0.580	1143	2027	
3 corner		3.22		4.228	4.840	0.612	884		
4 corner		3.33		4.291	4.960	0.669	1042	1884	
4 cable		2.63		4.388	4.945	0.557	842		
5	20.45	————	4.167	4.199	4.840	0.641	3121		
6		————		4.752	5.250	0.498			

Run number	208	DM Shot number	38	Date	12/17/90	Time	13:18

Connection	Single coil	Total inlet flow	43.268 g/s	Bm	4.347 T	Im	23 kA
Mode	AC	Inlet pressure	6.026 atm	Tm	1 s	Flat top	3 s
Description	Single trapezoid	Inlet temperature	4.368 K	Bm/Tm	4.347 T/s	Im/Tm	23.00 kA/s
				1/Tm	1.000 1/s		

Waveform



T1 = 1 s
T2 = 3 s

Im = 23 kA

Tm = T1

Quench ? No

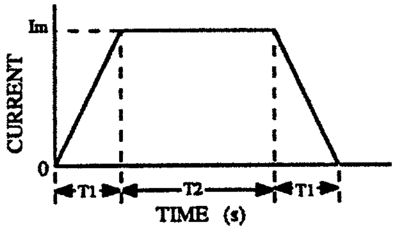
Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT			
1	9.728	———	4.368	4.376	4.670	0.294			
2		———		4.343	4.735	0.392	966.4		3661.2
3 cable	12.78	2.193		4.505	4.817	0.312	289.1	628	
3 corner		3.041		4.291	4.630	0.339	338.9		
4 corner		3.472		4.36	4.725	0.365	408.1	709.8	
4 cable		2.479		4.451	4.751	0.300	301.7		
5	20.76	———	4.189	4.269	4.620	0.351	1357		
6		———		4.804	5.077	0.273			

Run number	209	DM Shot number	39	Date	12/17/90	Time	13:28

Connection	Single coil	Total inlet flow	43.28 g/s	Bm	4.536 T	Im	24 kA
Mode	AC	Inlet pressure	5.106 atm	Tm	1 s	Flat top	3 s
Description	Single trapezoid	Inlet temperature	4.367 K	Bm/Tm	4.536 T/s	Im/Tm	24.00 kA/s
				1/Tm	1.000 1/s		

Waveform



T1 = 1 s
T2 = 3 s

Im = 24 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
MC03, VB5-6,MC01

Quench time 1.09 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT			
1	10.04	———	4.367	4.384	4.910	0.526			
2		———		4.337	5.065	0.728	1936		9940.5
3 cable	12.93	2.353		4.505	5.150	0.645	695.2	1401.7	
3 corner		3.049		4.289	4.980	0.691	706.5		
4 corner		3.521		4.358	5.175	0.817	940.8	1679.8	
4 cable		2.595		4.45	5.123	0.673	739		
5	20.31	———	4.187	4.268	5.800	1.532	4923		
6		———		4.805	5.710	0.905			

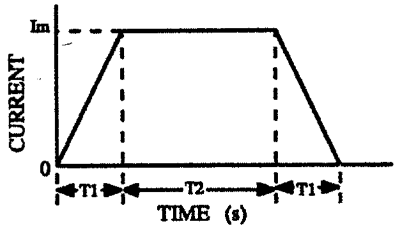
Run number 210 DM Shot number 40 Date 12/17/90 Time 13:41

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 40.3 g/s
Inlet pressure 6.098 atm
Inlet temperature 4.363 K

Bm 3.780 T
Tm 5 s
Bm/Tm 0.756 T/s
1/Tm 0.200 1/s
Im 20 kA
Flat top 3 s
Im/Tm 4.00 kA/s

Waveform



T1 = 5 s
T2 = 3 s

Im = 20 kA

Tm = T1

Quench ? No

Quench time _____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.4	———	4.363	4.392	4.587	0.195			
2		———		4.357	4.590	0.233			
3 cable	8.3	-.9		*	4.690	4.690			
3 corner		3.32		4.311	4.489	0.178			
4 corner		3.8		4.383	4.572	0.189			
4 cable		-.35		*	4.628	4.628			
5	21.6	———	4.184	4.271	4.506	0.235			
6		———		4.816	5.005	0.189			

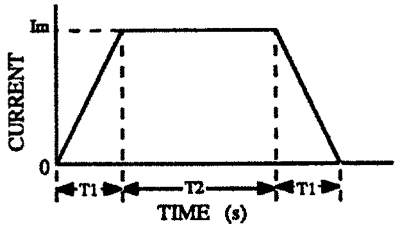
Run number 211 DM Shot number 69 Date 12/17/90 Time 13:51

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 40.542 g/s
Inlet pressure 6.098 atm
Inlet temperature 4.362 K

Bm 3.780 T
Tm 1 s
Bm/Tm 3.780 T/s
1/Tm 1.000 1/s
Im 20 kA
Flat top 3 s
Im/Tm 20.00 kA/s

Waveform



T1 = 1 s
T2 = 3 s

Im = 20 kA

Tm = T1

Quench ? No

Quench time _____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.44	———	4.362	4.383	4.635	0.252			
2		———		4.352	4.660	0.308	761.2		2380.2
3 cable	8.382	-.54		*	4.740	4.740	?	246.8	
3 corner		3.349		4.31	4.546	0.236	246.8		
4 corner		3.798		4.38	4.633	0.253	294.2	294.2	
4 cable		-.3		*	4.677	4.677	?		
5	21.72	———	4.182	4.277	4.554	0.277	1078		
6		———		4.811	5.036	0.225			

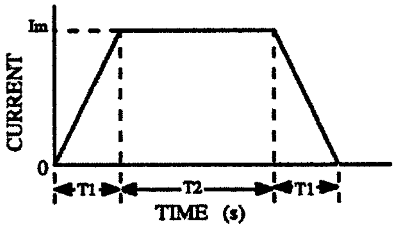
Run number 212 DM Shot number 70 Date 12/17/90 Time 14:02

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 40.91 g/s
Inlet pressure 6.098 atm
Inlet temperature 4.361 K

Bm 3.780 T
Tm .5 s
Bm/Tm 7.560 T/s
1/Tm 2.000 1/s
Im 20 kA
Flat top 3 s
Im/Tm 40.00 kA/s

Waveform



T1 = 0.5 s
T2 = 3 s
Im = 20 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.57	—	4.361	4.383	4.692	0.309			
2		—		4.35	4.730	0.380	967.6		2967.8
3 cable	8.49	-.58		*	4.795	4.795	?	312.2	
3 corner		3.315		4.309	4.605	0.296	312.2		
4 corner		3.796		4.38	4.696	0.316	371	371	
4 cable		-.38		*	4.728	4.728	?		
5	21.85	—	4.18	4.274	4.606	0.332	1317		
6		—		4.812	5.076	0.264			

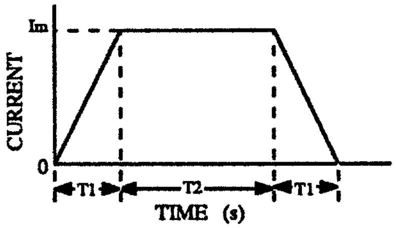
Run number 213 DM Shot number 71 Date 12/17/90 Time 14:12

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 40.656 g/s
Inlet pressure 6.074 atm
Inlet temperature 4.361 K

Bm 3.780 T
Tm .3 s
Bm/Tm 12.600 T/s
1/Tm 3.333 1/s
Im 20 kA
Flat top 3 s
Im/Tm 66.67 kA/s

Waveform



T1 = 0.3 s
T2 = 3 s
Im = 20 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.52	—	4.361	4.389	4.755	0.366			
2		—		4.353	4.808	0.455	1181		3671.1
3 cable	8.366	-.46		*	4.860	4.860	?	387.3	
3 corner		3.367		4.309	4.675	0.366	387.3		
4 corner		3.821		4.381	4.772	0.391	546.8	546.8	
4 cable		-.21		*	4.790	4.790	?		
5	21.77	—	4.181	4.276	4.669	0.393	1556		
6		—		4.815	5.120	0.305			

Run number 214 DM Shot number 72 Date 12/17/90 Time 14:23

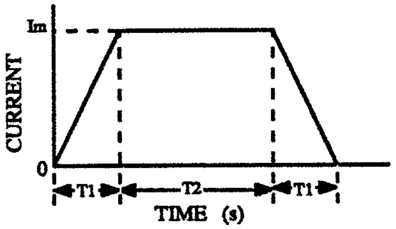
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 40.632 g/s
Inlet pressure 6.098 atm
Inlet temperature 4.365 K

Bm 4.347 T
Tm 1 s
Bm/Tm 4.347 T/s
1/Tm 1.000 1/s

Im 23 kA
Flat top 3 s
Im/Tm 23.00 kA/s

Waveform



T1 = 1 s
T2 = 3 s

Im = 23 kA

Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.48	———	4.365	4.388	4.691	0.303			
2		———		4.354	4.736	0.382	970.3		3021.6
3 cable	8.402	-.4		*	4.801	4.801	?	324.1	
3 corner		3.372		4.31	4.614	0.304	324.1		
4 corner		3.824		4.381	4.705	0.324	384.2	384.2	
4 cable		-.31		*	4.738	4.738	?		
5	21.75	———	4.185	4.279	4.617	0.338	1343		
6		———		4.815	5.083	0.268			

Run number 215 DM Shot number 73 Date 12/17/90 Time 14:38

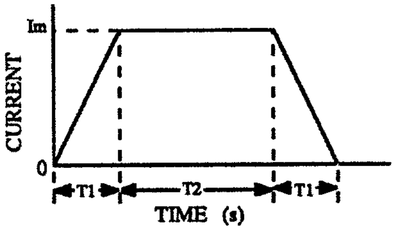
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 41.62 g/s
Inlet pressure 6.098 atm
Inlet temperature 4.362 K

Bm 3.780 T
Tm .3 s
Bm/Tm 12.600 T/s
1/Tm 3.333 1/s

Im 20 kA
Flat top 3 s
Im/Tm 66.67 kA/s

Waveform



T1 = 0.3 s
T2 = 3 s

Im = 20 kA

Tm = T1

Quench ? No

Quench time ______ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.28	———	4.362	4.385	4.750	0.365			
2		———		4.348	4.810	0.462	1192		3962.5
3 cable	10	2.461		4.508	4.875	0.367	401.1	811.8	
3 corner		3.227		4.296	4.695	0.399	410.7		
4 corner		0		*	4.779	4.779	?	391.7	
4 cable		2.689		4.456	4.795	0.339	391.7		
5	21.34	———	4.186	4.273	4.669	0.396	1567		
6		———		4.81	5.117	0.307			

Run number 216 DM Shot number 74 Date 12/17/90 Time 14:49

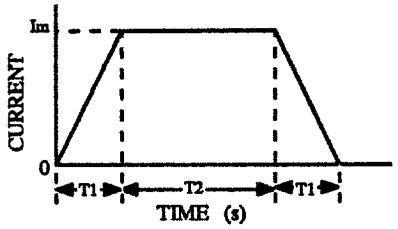
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 41.379 g/s
Inlet pressure 6.050 atm
Inlet temperature 4.365 K

Bm 4.347 T
Tm 1 s
Bm/Tm 4.347 T/s
1/Tm 1.000 1/s

Im 23 kA
Flat top 3 s
Im/Tm 23.00 kA/s

Waveform



T1 = 1 s
T2 = 3 s

Im = 23 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	10.24	———	4.365	4.383	4.686	0.303			
2		———		4.35	4.735	0.385	970.8		3242.1
3 cable	9.879	2.316		4.509	4.810	0.301	293.2	634.3	
3 corner		3.193		4.297	4.626	0.329	341.1		
4 corner		.098		*	4.710	4.710	?	297	
4 cable		2.605		4.462	4.740	0.278	297		
5	21.26	———	4.187	4.274	4.613	0.339	1340		
6		———		4.809	5.078	0.269			

Run number 217 DM Shot number 75 Date 12/17/90 Time 14:59

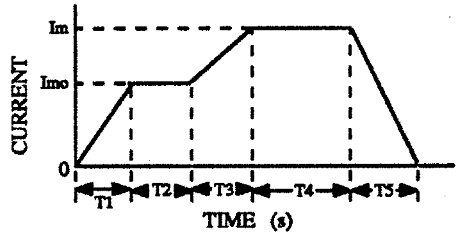
Connection Single coil
Mode AC
Description Two-step trapezoid

Total inlet flow 41.95 g/s
Inlet pressure 5.096 atm
Inlet temperature 4.364 K

Bm 5.670 T
Tm 5 s
Bm/Tm 1.134 T/s
1/Tm 0.200 1/s

Im 30 kA
Flat top 3 s
Im/Tm 6.00 kA/s

Waveform



T1 = 3.33 s
T2 = 3 s
T3 = 1.67 s
T4 = 3 s
T5 = 5 s

Im = 30 kA
Imo = 20 kA

Tm = T1+T2+T3

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6,MC03,VB3-4,VB1-2

Quench time 7.86 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.33	———	4.364	4.375	5.100	0.725			
2		———		4.341	5.360	1.019	2668		21700.1
3 cable	12.19	2.2		4.5	5.479	0.979	986.1	2128.1	
3 corner		3		4.288	5.315	1.027	1142		
4 corner		3.47		4.272	5.650	1.378	1661	2858	
4 cable		2.46		4.447	5.530	1.083	1197		
5	20.43	———	4.186	4.265	7.220	2.955	14046		
6		———		4.801	6.570	1.769			

Run number 218 DM Shot number 84 Date 12/17/90 Time 15:26

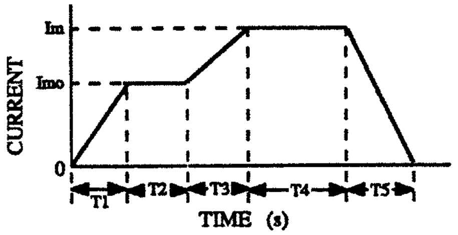
Connection Single coil
Mode AC
Description Two-step trapezoid

Total inlet flow 42.4 g/s
Inlet pressure 5.13 atm
Inlet temperature 4.365 K

Bm 5.670 T
Tm 5 s
Bm/Tm 1.134 T/s
1/Tm 0.200 1/s

Im 30 kA
Flat top 3 s
Im/Tm 6.00 kA/s

Waveform



T1 = 3.67 s
T2 = 3 s
T3 = 1.33 s
T4 = 3 s
T5 = 5 s

Im = 30 kA
Imo = 22 kA

Tm = T1+T2+T3

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6,MC03,VB3-4,VB1-2

Quench time 7.96 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.33	———	4.365	4.377	5.117	0.740			
2		———		4.341	5.380	1.039	2734		25508
3 cable	12.52	2.25		4.5	5.500	1.000	1039	2256	
3 corner		3.08		4.29	5.340	1.050	1217		
4 corner		3.49		4.357	5.725	1.368	1796	3091	
4 cable		2.49		4.447	5.598	1.151	1295		
5	20.55	———	4.186	4.265	7.770	3.505	17427		
6		———		4.804	6.750	1.946			

Run number 219 DM Shot number 76 Date 12/17/90 Time 15:38

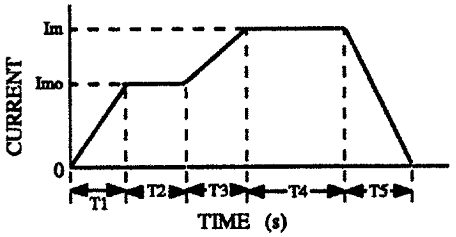
Connection Single coil
Mode AC
Description Two-step trapezoid

Total inlet flow 43.044 g/s
Inlet pressure 5.929 atm
Inlet temperature 4.376 K

Bm 5.103 T
Tm 2 s
Bm/Tm 2.552 T/s
1/Tm 0.500 1/s

Im 27 kA
Flat top 3 s
Im/Tm 13.50 kA/s

Waveform



T1 = 1 s
T2 = 1 s
T3 = 1 s
T4 = 3 s
T5 = 1 s

Im = 27 kA
Imo = 22 kA

Tm = T1+T2+T3

Quench ? No

Quench time s

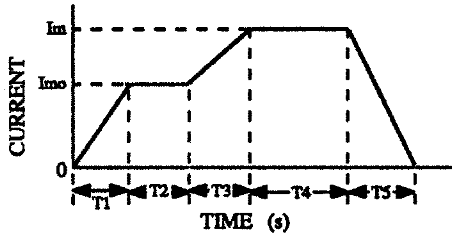
PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.753	———	4.376	4.389	4.755	0.366			
2		———		4.351	4.826	0.475	1196		4530.9
3 cable	12.741	2.223		4.51	4.891	0.381	367.1	788	
3 corner		3.028		4.299	4.710	0.411	420.9		
4 corner		3.458		4.368	4.810	0.442	507.6	883.9	
4 cable		2.45		4.456	4.822	0.366	376.3		
5	20.55	———	4.198	4.276	4.701	0.425	1663		
6		———		4.819	5.141	0.322			

Run number 220 DM Shot number 77 Date 12/17/90 Time 15:48

Connection Single coil
Mode AC
Description Two-step trapezoid
Total inlet flow 12.58 g/s
Inlet pressure 5.086 atm
Inlet temperature 4.367 K

Bm 5.670 T
Tm 2 s
Bm/Tm 2.835 T/s
1/Tm 0.500 1/s
Im 30 kA
Flat top 3 s
Im/Tm 15.00 kA/s

Waveform



T1 = 1 s
T2 = 1 s
T3 = 1 s
T4 = 3 s
T5 = 1 s

Im = 30 kA
Imo = 22 kA

Tm = T1+T2+T3

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
MC03,VB5-6,VB1-2,VB3-4,MC01

Quench time 2.91 s

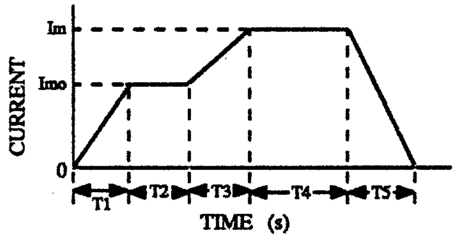
PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	2.91		4.367	4.381	5.137	0.756			
2				4.343	5.400	1.057	898.6		8294.2
3 cable	3.54	.68		4.502	5.530	1.028	335.2	638.7	
3 corner		.75		4.29	5.364	1.074	303.5		
4 corner		.81		4.36	5.775	1.415	434.8	836.9	
4 cable		.71		4.45	5.640	1.190	402.1		
5	6.13		4.189	4.266	8.130	3.864	5920		
6				4.804	6.870	2.066			

Run number 221 DM Shot number 78 Date 12/17/90 Time 15:59

Connection Single coil
Mode AC
Description Two-step trapezoid
Total inlet flow 43.143 g/s
Inlet pressure 5.910 atm
Inlet temperature 4.37 K

Bm 5.670 T
Tm 2.6 s
Bm/Tm 2.181 T/s
1/Tm 0.385 1/s
Im 30 kA
Flat top 3 s
Im/Tm 11.54 kA/s

Waveform



T1 = 1 s
T2 = 1 s
T3 = 1.6 s
T4 = 11 s
T5 = 1 s

Im = 30 kA
Imo = 22 kA

Tm = T1+T2+T3

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.753		4.37	4.394	4.818	0.424			
2				4.35	4.899	0.549	1397		5275.4
3 cable	12.74	2.267		4.509	4.950	0.441	444.9	933.6	
3 corner		3.036		4.296	4.773	0.477	488.7		
4 corner		3.464		4.365	4.877	0.512	588.4	1031.8	
4 cable		2.457		4.454	4.880	0.426	443.4		
5	20.65		4.193	4.273	4.763	0.490	1913		
6				4.82	5.190	0.370			

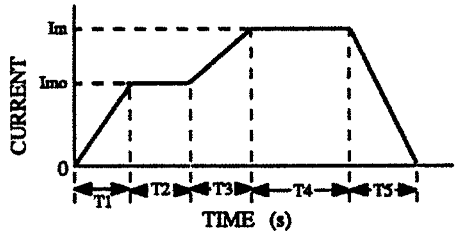
Run number 222 DM Shot number 79 Date 12/17/90 Time 16:10

Connection Single coil
Mode AC
Description Two-step trapezoid

Total inlet flow 42.604 g/s
Inlet pressure 5.977 atm
Inlet temperature 4.367 K

Bm 5.670 T
Tm 2.6 s
Bm/Tm 2.181 T/s
1/Tm 0.385 1/s
Im 30 kA
Flat top 11 s
Im/Tm 11.54 kA/s

Waveform



T1 = 1 s
T2 = 1 s
T3 = 1.6 s
T4 = 11 s
T5 = 1 s

Im = 30 kA
Imo = 22 kA

Tm = T1+T2+T3

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
				OUTLET					
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT			
1	9.454		4.367	4.387	4.832	0.445			
2				4.343	4.907	0.564	1410		5391.3
3 cable	12.57	2.267		4.503	4.952	0.449	450	951	
3 corner		2.984		4.291	4.775	0.484	501		
4 corner		3.433		4.359	4.878	0.519	604.9	1067.3	
4 cable		2.502		4.45	4.881	0.431	462.4		
5	20.58		4.188	4.267	4.757	0.490	1963		
6				4.809	5.190	0.381			

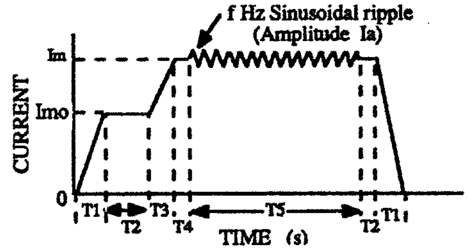
Run number 223 DM Shot number 80 Date 12/17/90 Time 16:22

Connection Single coil
Mode AC
Description Two-step trapezoid with ripple on flat top

Total inlet flow 37.88 g/s
Inlet pressure 5.078 atm
Inlet temperature 4.368 K

Bm 5.481 T
Tm 2.6 s
Bm/Tm 2.108 T/s
1/Tm 0.385 1/s
Im 29 kA
Flat top 11 s
Im/Tm 11.15 kA/s

Waveform



T1 = 1 s
T2 = 1 s
T3 = 1.6 s
T4 = 1 s
T5 = 9 s
Im = 29 kA
Imo = 22 kA
Ia = 400 A
f = 10 Hz

Tm = T1+T2+T3

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
MC03,VB5-6,VB1-2,MC01

Quench time 3.64 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
				OUTLET					
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT			
1	12.39		4.368	4.385	5.102	0.717			
2				4.343	5.355	1.012	3622		16590
3 cable	15.49	2.46		4.503	5.460	0.957	1126	2265	
3 corner		3.03		4.291	5.300	1.009	1139		
4 corner		3.49		4.36	5.650	1.290	1677	3047	
4 cable		2.72		4.45	5.530	1.080	1370		
5	10		4.189	4.263	7.440	3.177	7656		
6				4.806	6.620	1.814			

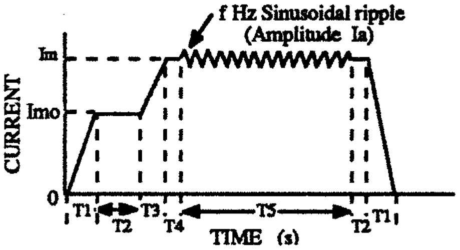
Run number 224 DM Shot number 81 Date 12/17/90 Time 16:34

Connection Single coil
Mode AC
Description Two-step trapezoid with ripple on flat top

Total inlet flow 41.27 g/s
Inlet pressure 5.929 atm
Inlet temperature 4.371 K

Bm 5.481 T
Tm 2.6 s
Bm/Tm 2.108 T/s
1/Tm 0.385 1/s
Im 29 kA
Flat top 9 s
Im/Tm 11.15 kA/s

Waveform



T1 = 1 s
T2 = 1 s
T3 = 1.6 s
T4 = 3 s
T5 = 5 s
Im = 29 kA
Imo = 22 kA
Ia = 400 A
f = 10 Hz

Tm = T1+T2+T3

Quench ? No

Quench time _____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	8.84	———	4.371	4.384	4.846	0.462			
2		———		4.348	4.942	0.594	1364		5427.3
3 cable	12.27	2.232		4.508	4.985	0.477	454.2	970	
3 corner		2.971		4.296	4.802	0.506	515.8		
4 corner		3.472		4.362	4.910	0.548	633.5	1095.3	
4 cable		2.523		4.451	4.907	0.456	461.8		
5	20.16	———	4.19	4.27	4.793	0.523	1998		
6		———		4.81	5.210	0.400			

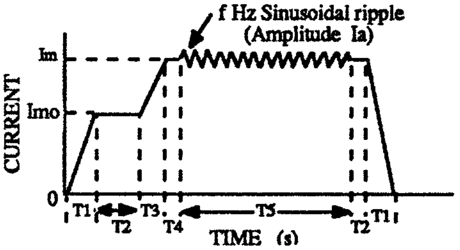
Run number 225 DM Shot number 82 Date 12/17/90 Time 16:47

Connection Single coil
Mode AC
Description Two-step trapezoid with ripple on flat top

Total inlet flow 38.179 g/s
Inlet pressure 5.953 atm
Inlet temperature 4.365 K

Bm 5.481 T
Tm 2.6 s
Bm/Tm 2.108 T/s
1/Tm 0.385 1/s
Im 29 kA
Flat top 9 s
Im/Tm 11.15 kA/s

Waveform



T1 = 1 s
T2 = 1 s
T3 = 1.6 s
T4 = 3 s
T5 = 5 s
Im = 29 kA
Imo = 22 kA
Ia = 600 A
f = 10 Hz

Tm = T1+T2+T3

Quench ? No

Quench time _____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	7.529	———	4.365	4.383	4.900	0.517			
2		———		4.342	5.080	0.738	1301		5803.2
3 cable	11.54	2.364		4.503	5.050	0.547	514.1	1111	
3 corner		3.052		4.29	4.875	0.585	596.9		
4 corner		3.553		4.358	4.990	0.632	736.1	1309.2	
4 cable		2.701		4.446	4.968	0.522	573.1		
5	19.11	———	4.187	4.265	4.850	0.585	2082		
6		———		4.807	5.248	0.441			

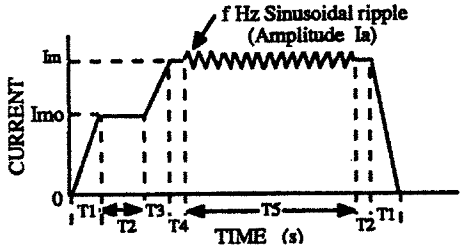
Run number 226 DM Shot number 83 Date 12/17/90 Time 16:57

Connection Single coil
Mode AC
Description Two-step trapezoid with ripple on flat top

Total inlet flow g/s
Inlet pressure 5.056 atm
Inlet temperature 4.365 K

Bm 5.481 T
Tm 2.6 s
Bm/Tm 2.108 T/s
1/Tm 0.385 1/s
Im 29 kA
Flat top 9 s
Im/Tm 11.15 kA/s

Waveform



T1 = 1 s
T2 = 1 s
T3 = 1.6 s
T4 = 3 s
T5 = 5 s
Im = 29 kA
Imo = 22 kA
Ia = 800 A
f = 10 Hz

Tm = T1+T2+T3

Quench ? Yes- Quench information ?

Quench detection sequence
VB5-6,MC03,MC01

Quench time -- s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]	
	INLET	OUTLET	INLET	OUTLET				
				INITIAL	PEAK	ΔT		
1		—	4.365	4.383	5.100	0.717		
2		—		4.341	5.360	1.019		
3 cable				4.502	5.475	0.973		
3 corner				4.291	5.315	1.024		
4 corner				4.359	5.675	1.316		
4 cable				4.434	5.550	1.116		
5		—	4.188	4.267	7.450	3.183		
6		—		4.804	6.660	1.856		

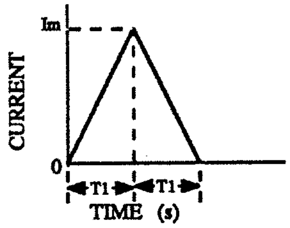
Run number 227 DM Shot number Date 12/18/90 Time 10:01

Connection Single coil
Mode AC
Description Single triangle

Total inlet flow g/s
Inlet pressure 5.600 atm
Inlet temperature 4.711 K

Bm 0.284 T
Tm 5 s
Bm/Tm 0.057 T/s
1/Tm 0.200 1/s
Im 1.5 kA
Flat top 0 s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s
Im = 1.5 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]	
	INLET	OUTLET	INLET	OUTLET				
				INITIAL	PEAK	ΔT		
1		—	4.711	x				
2		—		x				
3 cable				x				
3 corner				x				
4 corner				x				
4 cable				x				
5		—	4.543	x				
6		—		x				

Run number 228 DM Shot number 274 Date 12/18/90 Time 10:08

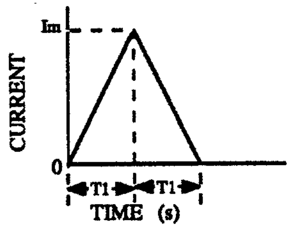
Connection Single coil
Mode AC
Description Single triangle

Total inlet flow ____ g/s
Inlet pressure 5.624 atm
Inlet temperature 4.706 K

Bm 0.284 T
Tm 5 s
Bm/Tm 0.057 T/s
1/Tm 0.200 1/s

Im 1.5 kA
Flat top 0 s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s
Im = 1.5 kA

Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]	
	INLET	OUTLET	INLET	OUTLET				
				INITIAL	PEAK	ΔT		
1		—	4.706	4.644				
2		—		4.622				
3 cable				4.734				
3 corner				4.544				
4 corner				4.624				
4 cable				4.672				
5		—	4.537	4.513				
6		—		*				

Run number 229 DM Shot number 275 Date 12/18/90 Time 10:17

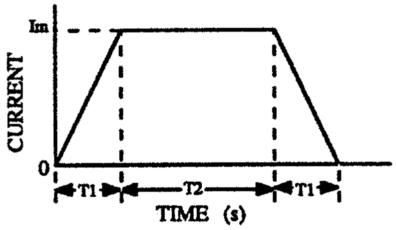
Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 25.81 g/s
Inlet pressure 5.624 atm
Inlet temperature 4.704 K

Bm 3.780 T
Tm 1 s
Bm/Tm 3.780 T/s
1/Tm 1.000 1/s

Im 20 kA
Flat top 3 s
Im/Tm 20.00 kA/s

Waveform



T1 = 1 s
T2 = 3 s
Im = 20 kA

Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]	
	INLET	OUTLET	INLET	OUTLET				
				INITIAL	PEAK	ΔT		
1	5.3	—	4.704	4.642	4.814	0.172		
2		—		*	4.927	4.927		
3 cable	7.56	.92		*	4.985	4.985		
3 corner		1.63		*	4.819	4.819		
4 corner		1.81		*	4.910	4.910		
4 cable		1.22		*	4.918	4.918		
5	12.95	—	4.534	*	4.796	4.796		
6		—		*	5.226	5.226		

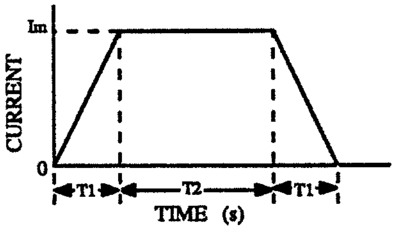
Run number 230 DM Shot number 276 Date 12/18/90 Time 10:29

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 25.99 g/s
Inlet pressure 5.648 atm
Inlet temperature 4.7 K

Bm 4.347 T
Im 23 kA
Tm 1 s
Flat top 3 s
Bm/Tm 4.347 T/s
Im/Tm 23.00 kA/s
1/Tm 1.000 1/s

Waveform



T1 = 1 s
T2 = 3 s

Im = 23 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	5.318	——	4.7	4.617	4.856	0.239			
2		——		4.616	4.992	0.376	1024		4068
3 cable	7.642	1.009		4.732	5.045	0.313	270.1	657.8	
3 corner		1.693		4.54	4.880	0.340	387.7		
4 corner		1.879		4.619	4.973	0.354	446.9	737.2	
4 cable		1.22		4.669	4.973	0.304	290.3		
5	13.03	——	4.532	4.509	4.847	0.338	1649		
6		——		5.019	5.251	0.232			

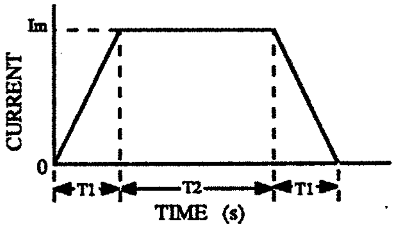
Run number 231 DM Shot number 277 Date 12/18/90 Time 10:40

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 25.698 g/s
Inlet pressure 5.789 atm
Inlet temperature 4.697 K

Bm 4.536 T
Im 24 kA
Tm 1 s
Flat top 3 s
Bm/Tm 4.536 T/s
Im/Tm 24.00 kA/s
1/Tm 1.000 1/s

Waveform



T1 = 1 s
T2 = 3 s

Im = 24 kA

Tm = T1

Quench ? No

VB5-6,VB3-4,VB1-2,MC02,MC01,MC 03

Quench time -- s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	5.213	——	4.697	4.63	4.875	0.245			
2		——		4.616	5.020	0.404	1074		4340.8
3 cable	7.575	1.072		4.731	5.068	0.337	315.8	728.6	
3 corner		1.696		4.541	4.907	0.366	412.8		
4 corner		1.869		4.619	5.000	0.381	470.9	784.2	
4 cable		1.22		4.668	4.995	0.327	313.3		
5	12.91	——	4.528	4.509	4.870	0.361	1754		
6		——		5.019	4.262				

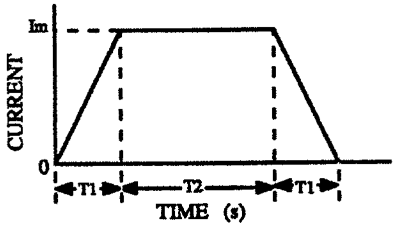
Run number 232 DM Shot number 278 Date 12/18/90 Time 10:51

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 23.25 g/s
Inlet pressure 5.646 atm
Inlet temperature 4.693 K

Bm 4.725 T
Tm 1 s
Bm/Tm 4.725 T/s
1/Tm 1.000 1/s
Im 25 kA
Flat top 3 s
Im/Tm 25.00 kA/s

Waveform



T1 = 1 s
T2 = 3 s
Im = 25 kA

Tm = T1

Quench ? Yes- Coils B and C initiated from joints.

Quench detection sequence VB5-6,VB3-4,VB1-2,MC02, MC01, MC03

Quench time – s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	4.98	—	4.693	4.652	5.075	0.423			
2		—		4.61	5.330	0.720	1938		51247.1
3 cable	7.07	.79		4.721	5.400	0.679	2734	3394.7	
3 corner		1.39		4.532	5.180	0.648	660.7		
4 corner		1.67		4.61	5.301	0.691	752	1405.4	
4 cable		1.15		4.662	5.255	0.593	653.4		
5	11.2	—	4.588	4.505			44509		
6		—		5.019	5.405	0.386			

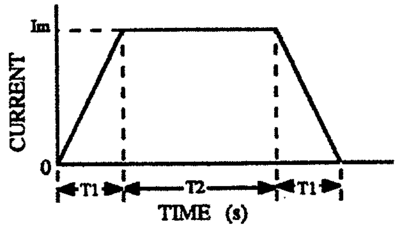
Run number 233 DM Shot number 279 Date 12/18/90 Time 11:03

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 25.706 g/s
Inlet pressure 5.837 atm
Inlet temperature X K

Bm 4.725 T
Tm 1.5 s
Bm/Tm 3.150 T/s
1/Tm 0.667 1/s
Im 25 kA
Flat top 3 s
Im/Tm 16.67 kA/s

Waveform



T1 = 1.5 s
T2 = 3 s
Im = 25 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	5.273	—		4.637	4.853	0.216			
2		—		4.601	4.987	0.386	1017		3985.4
3 cable	7.473	.644		4.736	5.040	0.304	169	574.3	
3 corner		1.696		4.527	4.868	0.341	405.3		
4 corner		1.862		4.608	4.966	0.358	450.6	740.1	
4 cable		1.207		4.66	4.967	0.307	289.5		
5	12.96	—		4.5	4.844	0.344	1654		
6		—		5.019	5.247	0.228			

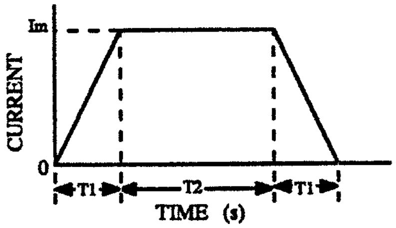
Run number 234 DM Shot number 280 Date 12/18/90 Time 11:14

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow g/s
Inlet pressure 5.444 atm
Inlet temperature 4.693 K

Bm 4.914 T
Im 26 kA
Tm 1.5 s
Flat top 3 s
Bm/Tm 3.276 T/s
Im/Tm 17.33 kA/s
1/Tm 0.667 1/s

Waveform



T1 = 1.5 s
T2 = 3 s

Im = 26 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
MC03,VB1-2,MC01,MC02

Quench time 1.58 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1		———	4.693	4.631	5.088	0.457			
2		———		4.602	5.385	0.783			
3 cable				4.722	5.437	0.715			
3 corner				4.526	5.296	0.770			
4 corner				4.606	5.465	0.859			
4 cable				4.656	5.400	0.744			
5		———	4.521	4.496	5.620	1.124			
6		———		5.005	5.602	0.597			

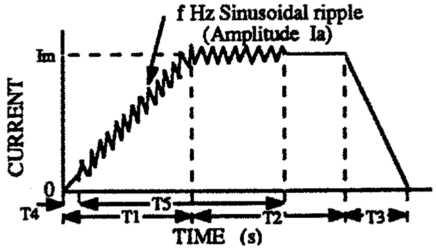
Run number 235 DM Shot number 281 Date 12/18/90 Time 11:31

Connection Single coil
Mode AC
Description Trapezoid with superimposed ripple

Total inlet flow 25.777 g/s
Inlet pressure 5.789 atm
Inlet temperature 4.688 K

Bm 4.725 T
Im 25 kA
Tm 1.5 s
Flat top 3 s
Bm/Tm 3.150 T/s
Im/Tm 16.67 kA/s
1/Tm 0.667 1/s

Waveform



T1 = 1.5 s
T2 = 3 s
T3 = 1 s
T4 = 0.4 s
T5 = 3 s

Im = 25 kA
Ia = 800 A
f = 10 Hz

Tm =T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	5.333	———	4.688	4.606	4.952	0.346			
2		———		4.609	5.160	0.551	1430		5589.5
3 cable	7.474	.715		4.722	5.181	0.459	268.3	827.9	
3 corner		1.688		4.531	5.032	0.501	559.6		
4 corner		1.854		4.611	5.144	0.533	635.6	1058.6	
4 cable		1.249		4.666	5.123	0.457	423		
5	12.97	———	4.519	4.5	4.994	0.494	2273		
6		———		5.012	5.330	0.318			

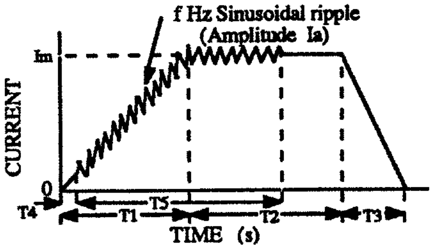
Run number 236 DM Shot number X Date 12/18/90 Time 11:43

Connection Single coil
Mode AC
Description Trapezoid with superimposed ripple

Total inlet flow g/s
Inlet pressure 5.789 atm
Inlet temperature 4.691 K

Bm 4.914 T Im 26 kA
Tm 1.5 s Flat top 3 s
Bm/Tm 3.276 T/s Im/Tm 17.33 kA/s
1/Tm 0.667 1/s

Waveform



T1 = 1.5 s
T2 = 3 s
T3 = 1 s
T4 = 0.4 s
T5 = 3 s

Im = 26 kA
Ia = 800 A
f = 10 Hz

Tm =T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
				OUTLET					
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT			
1		——	4.691	x					
2		——		x					
3 cable				x					
3 corner				x					
4 corner				x					
4 cable				x					
5		——	4.521	x					
6		——		x					

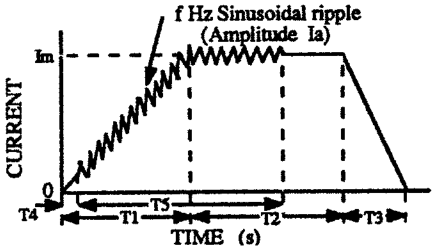
Run number 237 DM Shot number 282 Date 12/18/90 Time 11:50

Connection Single coil
Mode AC
Description Trapezoid with superimposed ripple

Total inlet flow 24.279 g/s
Inlet pressure 5.462 atm
Inlet temperature 4.686 K

Bm 5.103 T Im 27 kA
Tm 1.5 s Flat top 3 s
Bm/Tm 3.402 T/s Im/Tm 18.00 kA/s
1/Tm 0.667 1/s

Waveform



T1 = 1.5 s
T2 = 3 s
T3 = 1 s
T4 = 0.4 s
T5 = 3 s

Im = 26 kA
Ia = 800 A
f = 10 Hz

Tm =T1

Quench ? Yes- Quench information ?

Quench detection sequence
MC02,VB3-4,VB1-2,MC01,MC03

Quench time – s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
				OUTLET					
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT			
1	6.221	——	4.686	*	5.138	5.138			
2		——		4.604	5.548	0.944	2962		14549
3 cable	4.426	1.036		4.714	6.110	1.396	1130	2965	
3 corner		1.86		4.522	6.020	1.498	1835		
4 corner		2.013		4.6	6.370	1.770	2305	4245	
4 cable		1.781		4.656	6.160	1.504	1940		
5	13.632	——	4.515	4.489	5.370	0.881	4377		
6		——		5.048	5.480	0.432			

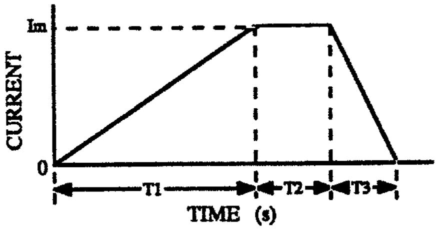
Run number 238 DM Shot number 286 Date 12/18/90 Time 13:36

Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 17.452 g/s
Inlet pressure 5.439 atm
Inlet temperature 4.683 K

Bm 5.670 T
Tm 7 s
Bm/Tm 0.810 T/s
1/Tm 0.143 1/s
Im 30 kA
Flat top 3 s
Im/Tm 4.29 kA/s

Waveform



T1 = 7 s
T2 = 3 s
T3 = 1 s

Im = 30 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
MC03, VB5-6, VB3-4,MC01,MC02

Quench time 6.81 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	3.83	———	4.683	4.583					
2		———		4.6	5.640	1.040	2065		15635.2
3 cable	5.12	.927		4.71	5.752	1.042	833.2	2317.2	
3 corner		1.833		4.524	5.630	1.106	1484		
4 corner		1.998		4.603	6.000	1.397	1962	3331	
4 cable		1.405		4.647	5.870	1.223	1369		
5	8.502	———	4.513	4.488	6.920	2.432	7922		
6		———		4.998	6.340	1.342			

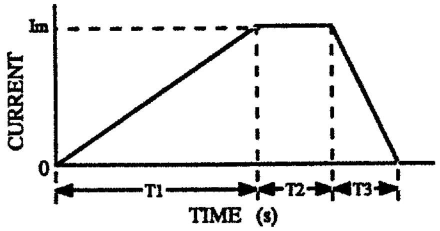
Run number 239 DM Shot number 285 Date 12/18/90 Time 13:47

Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 18.348 g/s
Inlet pressure 5.391 atm
Inlet temperature 4.679 K

Bm 5.670 T
Tm 8 s
Bm/Tm 0.709 T/s
1/Tm 0.125 1/s
Im 30 kA
Flat top s
Im/Tm 3.75 kA/s

Waveform



T1 = 8 s
T2 = 3 s
T3 = 1 s

Im = 30 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
MC03, VB5-6, VB3-4,MC01,MC02

Quench time 7.75 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	4.28	———	4.679	4.687					
2		———		4.581	5.630	1.049	2346		13945.9
3 cable	5.375	.931		4.7	5.720	1.020	833.9	2268.9	
3 corner		1.787		4.507	5.610	1.103	1435		
4 corner		1.998		4.588	5.890	1.302	1847	3108	
4 cable		1.373		4.646	5.770	1.124	1261		
5	8.693	———	4.508	4.479	6.500	2.021	6223		
6		———		5.067	6.125	1.058			

Run number 240 DM Shot number 283 Date 12/18/90 Time 13:58

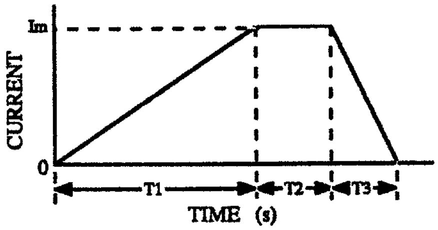
Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 21.424 g/s
Inlet pressure 5.468 atm
Inlet temperature 4.675 K

Bm 5.670 T
Tm 9 s
Bm/Tm 0.630 T/s
1/Tm 0.111 1/s

Im 30 kA
Flat top 3 s
Im/Tm 3.33 kA/s

Waveform



T1 = 9 s
T2 = 3 s
T3 = 1 s

Im = 30 kA

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
MC03,VB5-6,MC01,MC02

Quench time 8.73 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	3.382	———	4.675	4.675					
2		———		4.582	5.650	1.068	1860		18319.7
3 cable	6.516	1.063		4.7	5.780	1.080	975.7	2368.7	
3 corner		1.675		4.515	5.660	1.145	1393		
4 corner		1.944		4.591	6.040	1.449	1958	3330	
4 cable		1.393		4.644	6.875	2.231	1372		
5	11.526	———	4.507	4.479	6.900	2.421	10761		
6		———		5.029	6.340	1.311			

Run number 241 DM Shot number 284 Date 12/18/90 Time 14:09

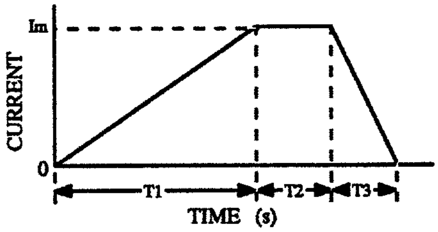
Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow 22.479 g/s
Inlet pressure 5.740 atm
Inlet temperature 4.675 K

Bm 5.670 T
Tm 11 s
Bm/Tm 0.515 T/s
1/Tm 0.091 1/s

Im 30 kA
Flat top 3 s
Im/Tm 2.73 kA/s

Waveform



T1 = 11 s
T2 = 3 s
T3 = 1 s

Im = kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	3.915	———	4.675	4.68	4.914	0.234			
2		———		4.581	5.095	0.514			3974.5
3 cable	6.784	1.092		4.698	5.117	0.419	377.9	924.1	
3 corner		1.691		4.507	4.970	0.463	546.2		
4 corner		1.919		4.587	5.070	0.483	636.5	1072.4	
4 cable		1.344		4.642	5.055	0.413	435.9		
5	11.78	———	4.506	4.48	4.930	0.450	1978		
6		———		5.065	5.300	0.235			

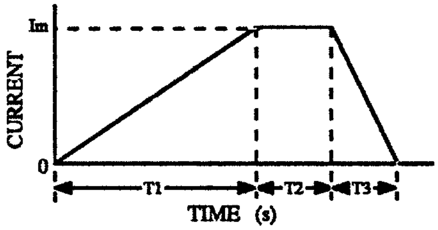
Run number 242 DM Shot number X Date 12/18/90 Time 14:20

Connection Single coil
Mode AC
Description Slow-ramp trapezoid

Total inlet flow ____ g/s
Inlet pressure 5.837 atm
Inlet temperature 4.672 K

Bm 5.670 T
Tm 10 s
Bm/Tm 0.567 T/s
1/Tm 0.100 1/s
Im 30 kA
Flat top ____ s
Im/Tm 3.00 kA/s

Waveform



T1 = 10 s
T2 = 3 s
T3 = 1 s

Im = 30 kA

Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1		———	4.672	x					
2		———		x					
3 cable				x					
3 corner				x					
4 corner				x					
4 cable				x					
5		———	4.501	x					
6		———		x					

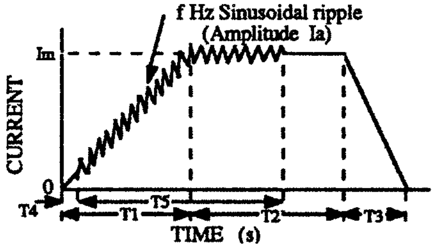
Run number 243 DM Shot number 287 Date 12/18/90 Time 14:31

Connection Single coil
Mode AC
Description Trapezoid with superimposed ripple

Total inlet flow 25.813 g/s
Inlet pressure 5.861 atm
Inlet temperature 4.672 K

Bm 5.670 T
Tm 9 s
Bm/Tm 0.630 T/s
1/Tm 0.111 1/s
Im 30 kA
Flat top 3 s
Im/Tm 3.33 kA/s

Waveform



T1 = 9 s
T2 = 3 s
T3 = 1 s
T4 = 2 s
T5 = 9 s

Im = 30 kA
Ia = 800 A
f = 10 Hz

Tm =T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	5.453	———	4.672	4.62	5.128	0.508			
2		———		4.591	5.455	0.864	2249		8869.8
3 cable	7.68	1.018		4.697	5.450	0.753	570.5	1527.5	
3 corner		1.815		4.509	5.328	0.819	957		
4 corner		1.939		4.59	5.445	0.855	1055	1680.3	
4 cable		1.186		4.644	5.380	0.736	625.3		
5	12.68	———	4.501	4.477	5.250	0.773	3413		
6		———		4.989	5.482	0.493			

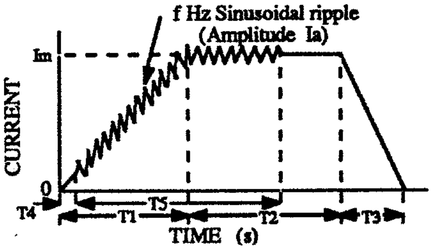
Run number 244 DM Shot number 288 Date 12/18/90 Time 14:43

Connection Single coil
Mode AC
Description Trapezoid with superimposed ripple

Total inlet flow 25.698 g/s
Inlet pressure 5.861 atm
Inlet temperature 4.672 K

Bm 5.670 T
Im 30 kA
Tm 8 s
Flat top 3 s
Bm/Tm 0.709 T/s
Im/Tm 3.75 kA/s
1/Tm 0.125 1/s

Waveform



T1 = 8 s
T2 = 3 s
T3 = 1 s
T4 = 2 s
T5 = 8 s

Im = 30 kA
Ia = 800 A
f = 10 Hz

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT			
1	5.401		4.672	4.626	5.120	0.494			
2				4.586	5.440	0.854	2198		8656.9
3 cable	7.667	1.023		4.701	5.432	0.731	564.5	1493.1	
3 corner		1.792		4.513	5.308	0.795	928.6		
4 corner		1.908		4.592	5.428	0.836	1018	1637.8	
4 cable		1.195		4.647	5.364	0.717	619.8		
5	12.63		4.503	4.481	5.230	0.749	3328		
6				4.92	5.474	0.554			

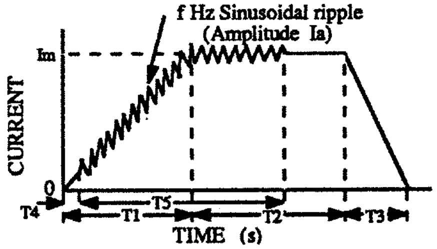
Run number 245 DM Shot number 289 Date 12/18/90 Time 14:54

Connection Single coil
Mode AC
Description Trapezoid with superimposed ripple

Total inlet flow g/s
Inlet pressure 5.665 atm
Inlet temperature 4.672 K

Bm 5.670 T
Im 30 kA
Tm 7 s
Flat top 3 s
Bm/Tm 0.810 T/s
Im/Tm 4.29 kA/s
1/Tm 0.143 1/s

Waveform



T1 = 7 s
T2 = 3 s
T3 = 1 s
T4 = 2 s
T5 = 7 s

Im = 30 kA
Ia = 800 A
f = 10 Hz

Tm = T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
VB5-6,MC03,MC02,MC01

Quench time 6.811 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT			
1	X		4.672	4.646	5.252	0.606			
2				4.586	5.670	1.084	X		
3 cable	X	X		4.7	5.795	1.095	X		
3 corner		X		4.512	5.695	1.183	X		
4 corner		X		4.591	6.160	1.569	X		
4 cable		X		4.648	6.020	1.372	X		
5	X		4.502	4.478	7.900	3.422	X		
6				4.994	6.740	1.746			

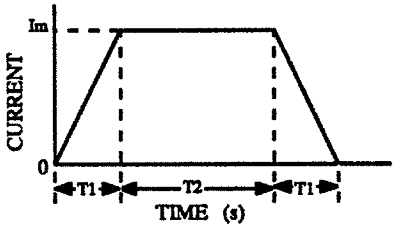
Run number 246 DM Shot number 290 Date 12/18/90 Time 15:29

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 26.1 g/s
Inlet pressure 6.002 atm
Inlet temperature 6.224 K

Bm	3.780 T	Im	20 kA
Tm	5 s	Flat top	3 s
Bm/Tm	0.756 T/s	Im/Tm	4.00 kA/s
1/Tm	0.200 1/s		

Waveform



T1 = 5 s
T2 = 3 s

Im = 20 kA

Tm = T1

Quench ?

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	5.504	—	6.224	5.689	5.840	0.151			
2		—		6.064	6.235	0.171	970		5174
3 cable	7.716	1.001		6.068	6.220	0.152	263	651	
3 corner		1.731		5.94	6.094	0.154	388		
4 corner		1.936		6.087	6.245	0.158	469	763	
4 cable		1.242		6.04	6.184	0.144	294		
5	12.88	—	6.081	5.952	6.108	0.156	2790		
6		—		6.196	6.334	0.138			

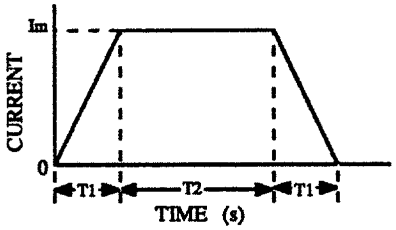
Run number 247 DM Shot number 291 Date 12/18/90 Time 15:40

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 26.1 g/s
Inlet pressure 6.050 atm
Inlet temperature 6.245 K

Bm	3.780 T	Im	20 kA
Tm	1.5 s	Flat top	3 s
Bm/Tm	2.520 T/s	Im/Tm	13.33 kA/s
1/Tm	0.667 1/s		

Waveform



T1 = 1.5 s
T2 = 3 s

Im = 20 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	5.504	—	6.245	5.729	5.882	0.153			
2		—		6.093	6.292	0.199	1136		4464.4
3 cable	7.716	1.001		6.095	6.271	0.176	292	745.7	
3 corner		1.731		5.967	6.153	0.186	453.7		
4 corner		1.936		6.114	6.302	0.188	539.9	884.7	
4 cable		1.242		6.063	6.235	0.172	344.8		
5	12.88	—	6.1	5.979	6.152	0.173	1698		
6		—		6.22	6.370	0.150			

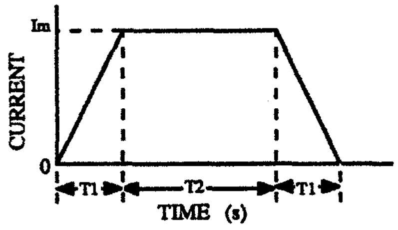
Run number 248 DM Shot number 292 Date 12/18/90 Time 15:51

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 25.98 g/s
Inlet pressure 6.190 atm
Inlet temperature 6.253 K

Bm 3.780 T
Tm .75 s
Bm/Tm 5.040 T/s
1/Tm 1.333 1/s
Im 20 kA
Flat top 3 s
Im/Tm 26.67 kA/s

Waveform



T1 = 0.75 s
T2 = 3 s
Im = 20 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	5.474	—	6.253	5.739	5.883	0.144			
2		—		6.1	6.295	0.195	1007		4019.6
3 cable	7.716	1.029		6.1	6.276	0.176	276.6	671.8	
3 corner		1.78		5.973	6.155	0.182	395.2		
4 corner		1.978		6.115	6.304	0.189	481.2	802.8	
4 cable		1.288		6.067	6.236	0.169	321.6		
5	12.79	—	6.106	5.979	6.151	0.172	1538		
6		—		6.225	6.364	0.139			

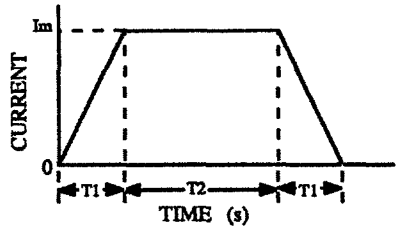
Run number 249 DM Shot number 293 Date 12/18/90 Time 16:02

Connection Single coil
Mode AC
Description Single trapezoid

Total inlet flow 23.287 g/s
Inlet pressure 5.910 atm
Inlet temperature 6.238 K

Bm 3.780 T
Tm .3 s
Bm/Tm 12.600 T/s
1/Tm 3.333 1/s
Im 20 kA
Flat top 3 s
Im/Tm 66.67 kA/s

Waveform



T1 = 0.3 s
T2 = 3 s
Im = 20 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	5.6	—	6.238	5.712	5.950	0.238			
2		—		6.065	6.368	0.303	1726		6586.4
3 cable	4.797	1.163		6.072	6.339	0.267	539.6	1163.3	
3 corner		1.767		5.939	6.216	0.277	623.7		
4 corner		1.989		6.082	6.364	0.282	759.7	1332.1	
4 cable		1.357		6.039	6.293	0.254	572.4		
5	12.89	—	6.075	5.947	6.201	0.254	2365		
6		—		6.201	6.410	0.209			

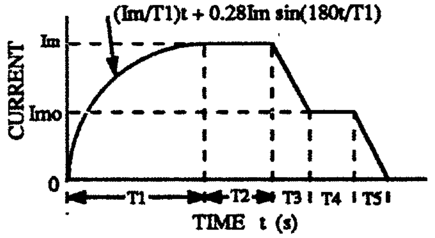
Run number 250 DM Shot number 294 Date 12/18/90 Time 16:27

Connection Single coil
Mode AC
Description Two-step-down pulse

Total inlet flow g/s
Inlet pressure 6.215 atm
Inlet temperature 4.695 K

Bm 5.670 T
Tm 6 s
Bm/Tm 0.945 T/s
1/Tm 0.167 1/s
Im 30 kA
Flat top 3 s
Im/Tm 5.00 kA/s

Waveform



T1 = 6 s
T2 = 3 s
T3 = 1.9 s
T4 = 3 s
T5 = 1 s

Im = 30 kA
Imo = 20 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X	—	4.695	4.653	4.960	0.307			
2		—		5.742			X		
3 cable	X	X		4.776	5.088	0.312	X		
3 corner		X		4.646	4.906	0.260	X		
4 corner		X		5.778			X		
4 cable		X		5.984			X		
5	X	—	4.525	5.418			X		
6		—		5.75					

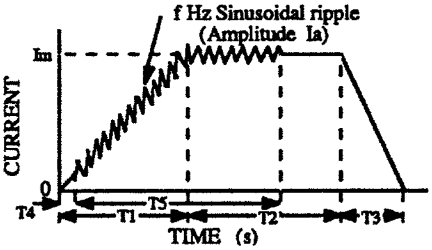
Run number 251 DM Shot number 295 Date 12/18/90 Time 16:37

Connection Single coil
Mode AC
Description Trapezoid with superimposed ripple

Total inlet flow 43.742 g/s
Inlet pressure 6.142 atm
Inlet temperature 4.693 K

Bm 5.670 T
Tm 7 s
Bm/Tm 0.810 T/s
1/Tm 0.143 1/s
Im 30 kA
Flat top 3 s
Im/Tm 4.29 kA/s

Waveform



T1 = 7 s
T2 = 3 s
T3 = 1 s
T4 = 2 s
T5 = 7 s

Im = 30 kA
Ia = 800 A
f = 20 Hz

Tm =T1

Quench ? No

Quench time s

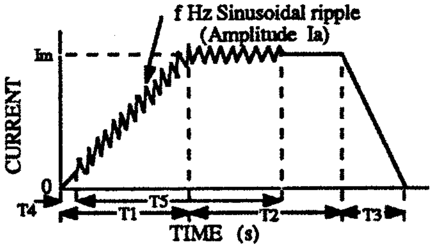
PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	9.982	—	4.693	4.635	5.246	0.611			
2		—		4.647	5.460	0.813	2296		8618
3 cable	12.92	2.252		4.76	5.455	0.695	694.5	1545.9	
3 corner		3.13		4.579	5.300	0.721	851.4		
4 corner		3.535		4.666	5.455	0.789	1004	1737.1	
4 cable		2.546		4.727	5.380	0.653	733.1		
5	20.84	—	4.523	4.56	5.240	0.680	3039		
6		—		5.061	5.574	0.513			

Run number 252 DM Shot number 296 Date 12/18/90 Time 16:48

Connection Single coil
Mode AC
Description Trapezoid with superimposed ripple
Total inlet flow 41.22 g/s
Inlet pressure 5.598 atm
Inlet temperature 5.586 K

Bm 5.670 T
Im 30 kA
Tm 6 s
Flat top 3 s
Bm/Tm 0.945 T/s
Im/Tm 5.00 kA/s
1/Tm 0.167 1/s

Waveform



T1 = 6 s
T2 = 3 s
T3 = 1 s
T4 = 1.5 s
T5 = 6.5 s

Im = 30 kA
Ia = 800 A
f = 20 Hz

Tm =T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
MC03,VB5-6,VB3-4,VB1-2

Quench time 5.71 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	11.5	—	5.586	4.64	5.459	0.819			
2		—		4.65	5.761	1.111	3995		14731
3 cable	15.53	2.393		4.769	5.782	1.013	1228	2589	
3 corner		3.117		4.582	5.640	1.058	1361		
4 corner		3.554		4.667	5.840	1.173	1731	3141	
4 cable		2.763		4.728	5.760	1.032	1410		
5	14.19	—	16.31	4.561	6.325	1.764	5006		
6		—		5.064	6.220	1.156			

Run number 253 DM Shot number 297 Date 12/18/90 Time 16:59

Connection Single coil
Mode AC
Description Miss shot
Total inlet flow 37.006 g/s
Inlet pressure 5.131 atm
Inlet temperature 4.697 K

Bm T
Im X kA
Tm X s
Flat top s
Bm/Tm T/s
Im/Tm kA/s
1/Tm 1/s

Waveform

Quench ? Yes- Joint?

Quench detection sequence
NOT AVAILABLE

Quench time 5.59 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	7.039	—	4.697	4.642	5.340	0.698			
2		—		4.653	5.620	0.967	2226		23137
3 cable	11.27	2.779		4.769	5.700	0.931	1368	2762	
3 corner		3.332		4.581	5.556	0.975	1394		
4 corner		3.725		4.671	5.925	1.254	1986	3669	
4 cable		3.078		4.734	5.795	1.061	1683		
5	18.697	—	4.526	4.567	7.610	3.043	14480		
6		—		5.064	6.840	1.776			

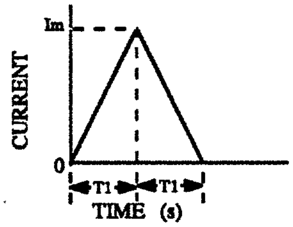
Run number 254 DM Shot number 133 Date 12/19/90 Time 10:12

Connection Series with U1 & U2 coils
Mode AC
Description Single triangle

Total inlet flow g/s
Inlet pressure 6.026 atm
Inlet temperature 4.321 K

Bm 0.461 T
Tm 5 s
Bm/Tm 0.092 T/s
1/Tm 0.200 1/s
Im 1.5 kA
Flat top 0 s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s
Im = 1.5 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s] INLET	MASS FLOW [g/s] OUTLET	TEMPERATURE [K] INLET	TEMPERATURE [K] OUTLET INITIAL	TEMPERATURE [K] OUTLET PEAK	TEMPERATURE [K] OUTLET ΔT	AC LOSS [J]
1	X	—	4.321	4.341			
2		—		4.298			X
3 cable	X	X		4.464			X
3 corner		X		4.247			X
4 corner		X		5.012			X
4 cable		X		X			X
5	X	—	4.138	X			X
6		—		X			

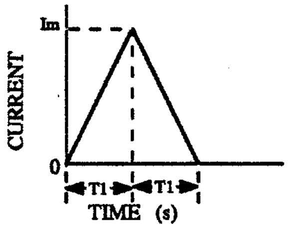
Run number 255 DM Shot number 134 Date 12/19/90 Time 10:20

Connection Series with U1 & U2 coils
Mode AC
Description Single triangle

Total inlet flow g/s
Inlet pressure 6.026 atm
Inlet temperature 4.32 K

Bm 0.461 T
Tm 5 s
Bm/Tm 0.092 T/s
1/Tm 0.200 1/s
Im 1.5 kA
Flat top 0 s
Im/Tm 0.30 kA/s

Waveform



T1 = 5 s
Im = 1.5 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s] INLET	MASS FLOW [g/s] OUTLET	TEMPERATURE [K] INLET	TEMPERATURE [K] OUTLET INITIAL	TEMPERATURE [K] OUTLET PEAK	TEMPERATURE [K] OUTLET ΔT	AC LOSS [J]
1	X	—	4.32	4.344			
2		—		4.3			X
3 cable	X	X		4.466			X
3 corner		X		4.249			X
4 corner		X		5.014			X
4 cable		X		X			X
5	X	—	4.14	X			X
6		—		X			

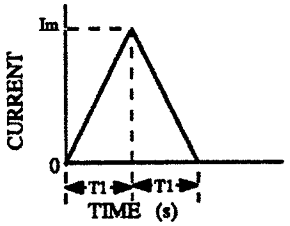
Run number 256 DM Shot number 135 Date 12/19/90 Time 10:28

Connection Series with U1 & U2 coils
Mode AC
Description Single triangle

Total inlet flow ____ g/s
Inlet pressure 6.002 atm
Inlet temperature 4.325 K

Bm 1.844 T
Tm .75 s
Bm/Tm 2.459 T/s
1/Tm 1.333 1/s
Im 6 kA
Flat top 0 s
Im/Tm 8.00 kA/s

Waveform



T1 = 0.75 s
Im = 6 kA
Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X		4.325	4.346	4.419	0.073			
2				4.304	4.412	0.108	X		231.55
3 cable	12.77	X		4.469	4.566	0.097	X		
3 corner		X		4.251	4.357	0.106	X		
4 corner		.536		5.015			X	40.05	
4 cable		.249		6.809	6.886	0.077	40.05		
5	3.792		4.144	5.914	5.978	0.064	191.5		
6				X					

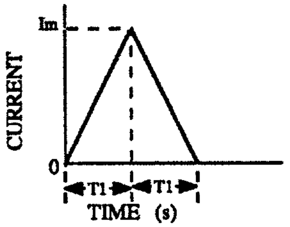
Run number 257 DM Shot number 136 Date 12/19/90 Time 10:41

Connection Series with U1 & U2 coils
Mode AC
Description Single triangle

Total inlet flow 17.673 g/s
Inlet pressure 6.026 atm
Inlet temperature 4.324 K

Bm 3.688 T
Tm .75 s
Bm/Tm 4.917 T/s
1/Tm 1.333 1/s
Im 12 kA
Flat top 0 s
Im/Tm 16.00 kA/s

Waveform



T1 = 0.75 s
Im = 12 kA
Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	.997		4.324	4.351	4.507	0.156			
2				4.303	4.540	0.237	47.68		721.49
3 cable	12.82	.719		4.469	4.681	0.212	51.4	92.03	
3 corner		.601		4.251	4.483	0.232	40.63		
4 corner		.509		5.019			X	54.58	
4 cable		.143		6.814	7.000	0.186	54.58		
5	3.856		4.142	5.914	6.115	0.201	527.2		
6				X					

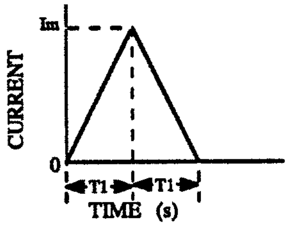
Run number 258 DM Shot number 137 Date 12/19/90 Time 10:53

Connection Series with U1 & U2 coils
Mode AC
Description Single triangle

Total inlet flow 17.65 g/s
Inlet pressure 5.977 atm
Inlet temperature 4.324 K

Bm 5.532 T
Tm .75 s
Bm/Tm 7.376 T/s
1/Tm 1.333 1/s
Im 18 kA
Flat top 0 s
Im/Tm 24.00 kA/s

Waveform



T1 = 0.75 s
Im = 18 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	.992	—	4.324	4.351	4.619	0.268			
2		—		4.303	4.730	0.427	86.93		1595.539
3 cable	12.84	.721		4.469	4.859	0.390	96.79	171.73	
3 corner		.594		4.252	4.670	0.418	74.94		
4 corner		.504		5.024			3.679	149.879	
4 cable		.186		6.81	7.290	0.480	146.2		
5	3.818	—	4.143	5.93	6.430	0.500	1187		
6		—		X					

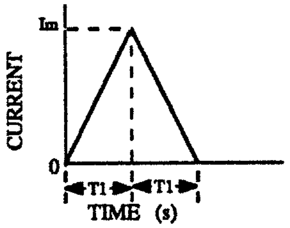
Run number 259 DM Shot number 138 Date 12/19/90 Time 11:04

Connection Series with U1 & U2 coils
Mode AC
Description Single triangle

Total inlet flow 17.776 g/s
Inlet pressure 5.977 atm
Inlet temperature 4.329 K

Bm 7.376 T
Tm .75 s
Bm/Tm 9.835 T/s
1/Tm 1.333 1/s
Im 24 kA
Flat top 0 s
Im/Tm 32.00 kA/s

Waveform



T1 = 0.75 s
Im = 24 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	1.09	—	4.329	4.359	4.791	0.432			
2		—		4.308	5.021	0.713	168.1		2869.04
3 cable	12.9	.711		4.473	5.159	0.686	174.6	303.3	
3 corner		.57		4.255	4.980	0.725	128.7		
4 corner		.516		5.035	5.590	0.555	43.94	370.64	
4 cable		.261		6.825	7.750	0.925	326.7		
5	3.786	—	4.146	5.785	6.750	0.965	2027		
6		—		X					

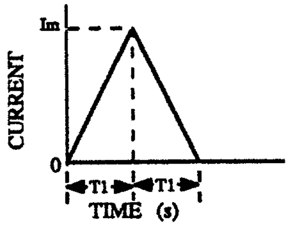
Run number 260 DM Shot number 139 Date 12/19/90 Time 11:15

Connection Series with U1 & U2 coils
Mode AC
Description Single triangle

Total inlet flow ____ g/s
Inlet pressure 5.007 atm
Inlet temperature 4.33 K

Bm 8.298 T
Tm .75 s
Bm/Tm 11.064 T/s
1/Tm 1.333 1/s
Im 27 kA
Flat top 0 s
Im/Tm 36.00 kA/s

Waveform



T1 = 0.75 s
Im = 27 kA

Tm = T1

Quench ? Yes- Coil C, but not crossover turn.

Quench detection sequence
USVB5-6,USMC03,USMC01,USMC0
2

Quench time .822 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X	—	4.33	4.368	5.640	1.272			
2		—		4.314	6.620	2.306	X		
3 cable	X	X		4.479	6.800	2.321	X		
3 corner		X		4.262	6.680	2.418	X		
4 corner		X		5.036	6.140	1.104	X		
4 cable		X		6.838	8.340	1.502	X		
5	X	—	4.151	5.935	6.900	0.965	X		
6		—		X					

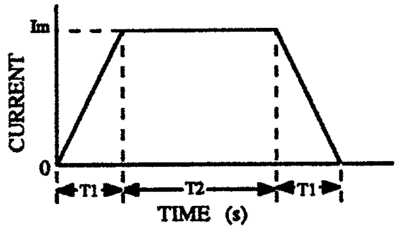
Run number 261 DM Shot number 140 Date 12/19/90 Time 11:27

Connection Series with U1 & U2 coils
Mode AC
Description Single trapezoid

Total inlet flow 17.703 g/s
Inlet pressure 5.813 atm
Inlet temperature 4.341 K

Bm 3.688 T
Tm 1 s
Bm/Tm 3.688 T/s
1/Tm 1.000 1/s
Im 12 kA
Flat top 0.5 s
Im/Tm 12.00 kA/s

Waveform



T1 = 1 s
T2 = 0.5 s

Im = 12 kA

Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	.902	—	4.341	4.375	4.510	0.135			
2		—		4.32	4.550	0.230	44.95		832.53
3 cable	12.88	.665		4.489	4.700	0.211	48.09	98.68	
3 corner		.736		4.345	4.500	0.155	50.59		
4 corner		.598		5.029			X	188	
4 cable		-.65		6.867	7.015	0.148	188		
5	3.921	—	4.158	5.971	6.142	0.171	500.9		
6		—		X					

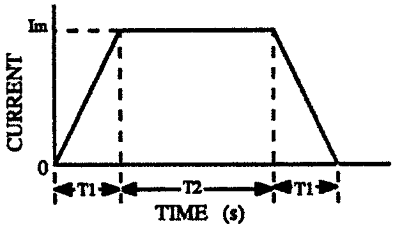
Run number 262 DM Shot number 141 Date 12/19/90 Time 11:38

Connection Series with U1 & U2 coils
Mode AC
Description Single trapezoid

Total inlet flow 17.93 g/s
Inlet pressure 5.861 atm
Inlet temperature 4.333 K

Bm 5.532 T
Tm 1 s
Bm/Tm 5.532 T/s
1/Tm 1.000 1/s
Im 18 kA
Flat top 0.5 s
Im/Tm 18.00 kA/s

Waveform



T1 = 1 s
T2 = 0.5 s

Im = 18 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	.992	———	4.333	4.351	4.606	0.255			
2		———		4.303	4.712	0.409	91.98		2295.666
3 cable	12.94	.671		4.476	4.855	0.379	89.79	183.82	
3 corner		.747		4.259	4.670	0.411	94.03		
4 corner		.606		5.03			4.866	562.866	
4 cable		-.68		6.84	7.370	0.530	558		
5	3.998	———	4.147	5.93	6.590	0.660	1457		
6		———		X					

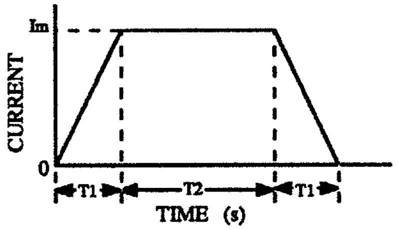
Run number 263 DM Shot number 143 Date 12/19/90 Time 11:49

Connection Series with U1 & U2 coils
Mode AC
Description Single trapezoid

Total inlet flow g/s
Inlet pressure 4.995 atm
Inlet temperature 4.333 K

Bm 7.376 T
Tm 1 s
Bm/Tm 7.376 T/s
1/Tm 1.000 1/s
Im 24 kA
Flat top 0.5 s
Im/Tm 24.00 kA/s

Waveform



T1 = 1 s
T2 = 0.5 s

Im = 24 kA

Tm = T1

Quench ? Yes- Coil C, but not crossover turn.

Quench detection sequence
USVB5-6,USMC03,USVB3-4,
USMC02

Quench time 1.4 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X	———	4.333	4.357	4.984	0.627			
2		———		4.261	5.725	1.464	X		
3 cable	X	X		4.489	7.280	2.791	X		
3 corner		X		4.26	7.550	3.290	X		
4 corner		X		5.036	5.930	0.894	X		
4 cable		X		6.84	8.100	1.260	X		
5	X	———	4.149	5.94	6.975	1.035	X		
6		———		X					

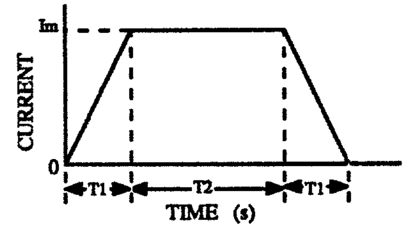
Run number 264 DM Shot number 144 Date 12/19/90 Time 13:21

Connection Series with U1 & U2 coils
Mode AC
Description Single trapezoid

Total inlet flow 17.974 g/s
Inlet pressure 5.073 atm
Inlet temperature 4.322 K

Bm 6.761 T
Tm 1 s
Bm/Tm 6.761 T/s
1/Tm 1.000 1/s
Im 22 kA
Flat top 0.5 s
Im/Tm 22.00 kA/s

Waveform



T1 = 1 s
T2 = 0.5 s

Im = 22 kA

Tm = T1

Quench ? Yes- Coil C crossover turn and other part.

Quench detection sequence
USMC03, USVB5-6,USMC01

Quench time 1.11 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	.859	———	4.322	4.336	4.774	0.438			
2		———		4.29	5.000	0.710	X		
3 cable	13.37	.65		4.468	5.195	0.727	X		
3 corner		.652		4.25	5.010	0.760	X		
4 corner		.643		5.021	5.493	0.472	X		
4 cable		-.623		6.801	8.050	1.249	X		
5	3.745	———	4.137	5.91	6.880	0.970	X		
6		———		X					

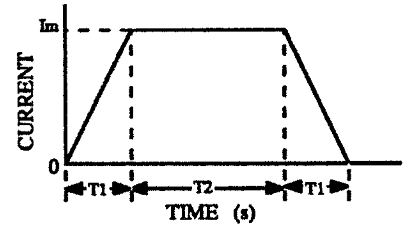
Run number 265 DM Shot number 145 Date 12/19/90 Time 13:32

Connection Series with U1 & U2 coils
Mode AC
Description Single trapezoid

Total inlet flow 17.729 g/s
Inlet pressure 5.953 atm
Inlet temperature 4.337 K

Bm 6.454 T
Tm 1 s
Bm/Tm 6.454 T/s
1/Tm 1.000 1/s
Im 21 kA
Flat top 0.5 s
Im/Tm 21.00 kA/s

Waveform



T1 = 1 s
T2 = 0.5 s

Im = 21 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	.911	———	4.337	4.36	4.688	0.328			
2		———		4.309	4.848	0.539	112.2		2915.95
3 cable	13.06	.584		4.479	4.990	0.511	104.2	211	
3 corner		.639		4.265	4.812	0.547	106.8		
4 corner		.649		5.026	5.136	0.110	13.75	723.75	
4 cable		-.61		6.84	7.800	0.960	710		
5	3.758	———	4.153	5.94	6.790	0.850	1869		
6		———		X					

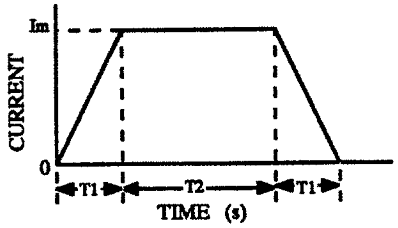
Run number 266 DM Shot number 146 Date 12/19/90 Time 13:44

Connection Series with U1 & U2 coils
Mode AC
Description Single trapezoid

Total inlet flow 24.369 g/s
Inlet pressure 5.023 atm
Inlet temperature 4.338 K

Bm 9.220 T
Tm .75 s
Bm/Tm 12.293 T/s
1/Tm 1.333 1/s
Im 30 kA
Flat top 0.3 s
Im/Tm 40.00 kA/s

Waveform



T1 = 0.75 s
T2 = 0.3 s
Im = 30 kA
Tm = T1

Quench ? Yes- Coils A, B and C.

Quench detection sequence
USVB5-6,USVB3-4,USMC02
USVB1-2,USMC01,USMC03,

Quench time .933 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT			
1	.883	———	4.338	4.375	12.800	8.425			
2		———		4.29	21.750	17.460	X		
3 cable	19.661	.6		4.45			X		
3 corner		.584		4.256			X		
4 corner		.656		5.035	6.060	1.025	X		
4 cable		-.605		6.847	12.975	6.128	X		
5	3.825	———	4.152	5.93	10.520	4.590	X		
6		———		X					

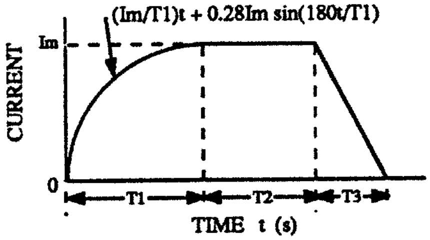
Run number 267 DM Shot number 174 Date 12/19/90 Time 14:18

Connection Series with U1 & U2 coils
Mode AC
Description Round-edged pulse

Total inlet flow 16.013 g/s
Inlet pressure 5.764 atm
Inlet temperature 4.356 K

Bm 3.688 T
Tm 1.7 s
Bm/Tm 2.169 T/s
1/Tm 0.588 1/s
Im 12 kA
Flat top 3 s
Im/Tm 7.06 kA/s

Waveform



T1 = 1.7 s
T2 = 3 s
T3 = 0.5 s
Im = 12 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT			
1	1.035	———	4.356	4.355	4.527	0.172			
2		———		4.306	4.569	0.263	52.03		1161.41
3 cable	12.08	.683		4.465	4.695	0.230	56.16	103.62	
3 corner		.592		4.229	4.490	0.261	47.46		
4 corner		.686		5.037	5.042	0.005	3.06	327.06	
4 cable		-.68		6.775	7.015	0.240	324		
5	2.898	———	4.116	5.874	6.350	0.476	678.7		
6		———		X					

Run number 268 DM Shot number 175 Date 12/19/90 Time 14:29

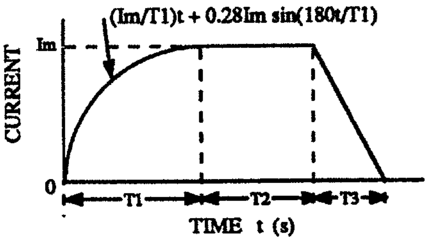
Connection Series with U1 & U2 coils
Mode AC
Description Round-edged pulse

Total inlet flow 16.969 g/s
Inlet pressure 5.837 atm
Inlet temperature 4.361 K

Bm 4.610 T
Tm 2.1 s
Bm/Tm 2.195 T/s
1/Tm 0.476 1/s

Im 15 kA
Flat top 3 s
Im/Tm 7.14 kA/s

Waveform



T1 = 2.1 s
T2 = 3 s
T3 = 0.5 s

Im = 15 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
				OUTLET					
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT			
1	1.066		4.361	4.342	4.555	0.213			
2				4.295	4.642	0.347	70.77		2386.52
3 cable	12.08	.608		4.442	4.760	0.318	67.59	129.75	
3 corner		.592		4.224	4.565	0.341	62.16		
4 corner		.589		5.034			X	711	
4 cable		-.67		6.75	7.930	1.180	711		
5	3.823		4.12	5.854	6.750	0.896	1475		
6				X					

Run number 269 DM Shot number 176 Date 12/19/90 Time 14:40

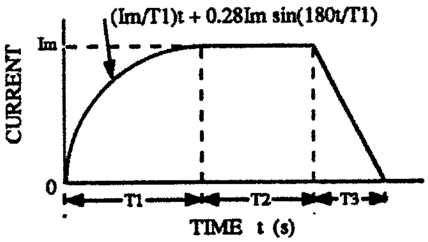
Connection Series with U1 & U2 coils
Mode AC
Description Round-edged pulse

Total inlet flow 16.752 g/s
Inlet pressure 5.552 atm
Inlet temperature 4.38 K

Bm 5.532 T
Tm 2.5 s
Bm/Tm 2.213 T/s
1/Tm 0.400 1/s

Im 18 kA
Flat top 3 s
Im/Tm 7.20 kA/s

Waveform



T1 = 2.5 s
T2 = 3 s
T3 = 0.5 s

Im = 18 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
				OUTLET					
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT			
1	.866		4.38	4.356	4.650	0.294			
2				4.317	4.781	0.464	82.5		4777.23
3 cable	12.01	.597		4.462	4.887	0.425	96.94	182.73	
3 corner		.567		4.245	4.700	0.455	85.79		
4 corner		.639		5.043			X	1321	
4 cable		-.73		6.558	9.330	2.772	1321		
5	3.876		4.14	5.89	7.720	1.830	3191		
6				X					

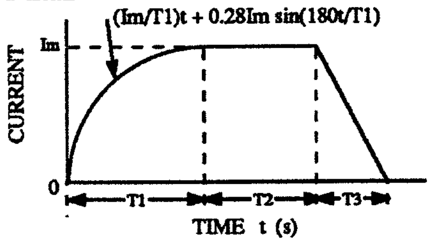
Run number 270 DM Shot number 177 Date 12/19/90 Time 14:51

Connection Series with U1 & U2 coils
Mode AC
Description Round-edged pulse

Total inlet flow 16.42 g/s
Inlet pressure 5.503 atm
Inlet temperature 4.401 K

Bm	6.147 T	Im	20 kA
Tm	2.8 s	Flat top	3 s
Bm/Tm	2.195 T/s	Im/Tm	7.14 kA/s
1/Tm	0.357 1/s		

Waveform



T1 = 2.8 s
T2 = 3 s
T3 = 0.5 s

Im = 20 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	.875	—	4.401	4.375	4.720	0.345			
2		—		4.338	4.900	0.562	X		7988.863
3 cable	11.75	.695		4.48	5.005	0.525	152.2	271.7	
3 corner		.586		4.261	4.825	0.564	119.5		
4 corner		.619		5.045			5.163	1866.163	
4 cable		-.67		6.84	11.380	4.540	1861		
5	3.795	—	4.164	5.94	9.800	3.860	5851		
6		—		X					

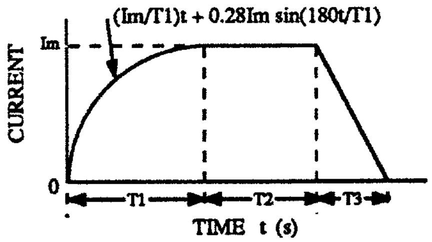
Run number 271 DM Shot number 178 Date 12/19/90 Time 15:02

Connection Series with U1 & U2 coils
Mode AC
Description Round-edged pulse

Total inlet flow g/s
Inlet pressure X atm
Inlet temperature 4.403 K

Bm	6.761 T	Im	22 kA
Tm	3 s	Flat top	3 s
Bm/Tm	2.254 T/s	Im/Tm	7.33 kA/s
1/Tm	0.333 1/s		

Waveform



T1 = 3 s
T2 = 3 s
T3 = 0.5 s

Im = 22 kA

Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	X	—	4.403	4.383	4.817	0.434			
2		—		4.337	5.045	0.708	X		
3 cable	X	X		4.476	5.155	0.679	X		
3 corner		X		4.26	4.990	0.730	X		
4 corner		X		5.034			X		
4 cable		X		6.862	13.650	6.788	X		
5	X	—	4.164	5.935	12.200	6.265	X		
6		—		X					

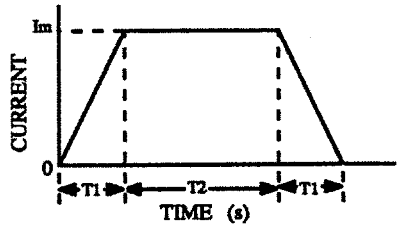
Run number 272 DM Shot number 179 Date 12/19/90 Time 15:38

Connection Series with U1 & U2 coils
Mode AC
Description Single trapezoid

Total inlet flow 16.919 g/s
Inlet pressure 5.977 atm
Inlet temperature 4.353 K

Bm 5.532 T
Tm .75 s
Bm/Tm 7.376 T/s
1/Tm 1.333 1/s
Im 18 kA
Flat top 0.5 s
Im/Tm 24.00 kA/s

Waveform



T1 = 0.75 s
T2 = 0.5 s
Im = 18 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT			
1	.98	—	4.353	4.33	4.617	0.287			
2		—		4.293	4.753	0.460	83.81		2497.55
3 cable	12.02	.068		4.439	4.869	0.430	98.5	185.74	
3 corner		.63		4.222	4.685	0.463	87.24		
4 corner		.624		5.012			12	691	
4 cable		-.61		6.74	7.550	0.810	679		
5	3.919	—	4.111	5.85	6.515	0.665	1537		
6		—		X					

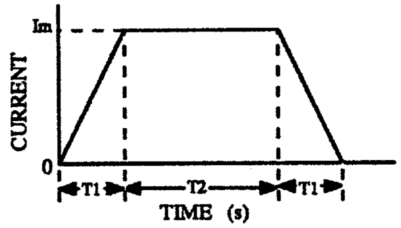
Run number 273 DM Shot number 180 Date 12/19/90 Time 15:48

Connection Series with U1 & U2 coils
Mode AC
Description Single trapezoid

Total inlet flow 16.951 g/s
Inlet pressure 5.953 atm
Inlet temperature 4.362 K

Bm 5.532 T
Tm 1.5 s
Bm/Tm 3.688 T/s
1/Tm 0.667 1/s
Im 18 kA
Flat top 0.5 s
Im/Tm 12.00 kA/s

Waveform



T1 = 1.5 s
T2 = 0.5 s
Im = 18 kA
Tm = T1

Quench ? No

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET INITIAL	OUTLET PEAK	OUTLET ΔT			
1	1.023	—	4.362	4.34	4.573	0.233			
2		—		4.303	4.670	0.367	70.33		1947.404
3 cable	12.05	.681		4.447	4.780	0.333	80.27	221.47	
3 corner		.633		4.231	4.599	0.368	141.2		
4 corner		.58		5.014			2.604	402.604	
4 cable		-.62		6.76	7.130	0.370	400		
5	3.878	—	4.121	5.87	6.508	0.638	1253		
6		—		X					

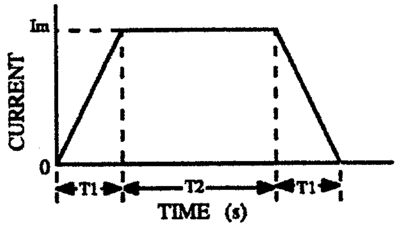
Run number 274 DM Shot number 181 Date 12/19/90 Time 16:00

Connection Series with U1 & U2 coils
Mode AC
Description Single trapezoid

Total inlet flow ____ g/s
Inlet pressure 5.910 atm
Inlet temperature 4.358 K

Bm 5.532 T
Tm 5 s
Bm/Tm 1.106 T/s
1/Tm 0.200 1/s
Im 18 kA
Flat top 0.5 s
Im/Tm 3.60 kA/s

Waveform



T1 = 5 s
T2 = 0.5 s
Im = 18 kA

Tm = T1

Quench ? No

Quench time ____ s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
				OUTLET					
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT			
1	X	______	4.358	4.34	4.532	0.192			
2		______		4.299	4.588	0.289	X		
3 cable	X	X		4.444	4.705	0.261	X		
3 corner		X		4.228	4.512	0.284	X		
4 corner		X		5.016			X		
4 cable		X		6.76	7.920	1.160	X		
5	X	______	4.118	5.867	6.207	0.340	X		
6		______		X					

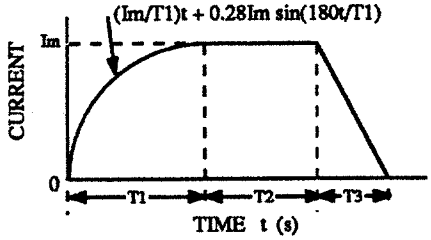
Run number 275 DM Shot number 182 Date 12/19/90 Time 16:11

Connection Series with U1 & U2 coils
Mode AC
Description Round-edged pulse

Total inlet flow 18.376 g/s
Inlet pressure 4.982 atm
Inlet temperature 4.357 K

Bm 6.761 T
Tm 1 s
Bm/Tm 6.761 T/s
1/Tm 1.000 1/s
Im 22 kA
Flat top 0.5 s
Im/Tm 22.00 kA/s

Waveform



T1 = 1 s
T2 = 0.5 s
T3 = 0.5 s
Im = 22 kA

Tm = T1

Quench ? Yes- Coil C crossover turn and other part.
Quench detection sequence
USMC03,USMC02

Quench time .798 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
				OUTLET					
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT			
1	.892	______	4.357	**					
2		______		4.302	5.010	0.708	X		
3 cable	13.686	.719		4.438	5.380	0.942	X		
3 corner		.636		4.231	5.200	0.969	X		
4 corner		.559		5.02	5.745	0.725	X		
4 cable		-.613		6.755	7.820	1.065	X		
5	3.798	______	4.118	5.865	6.725	0.860	X		
6		______		X					

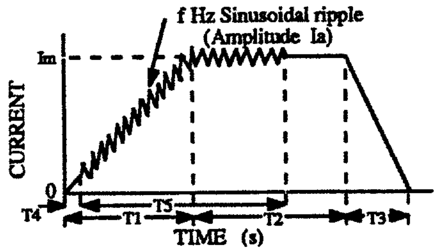
Run number 276 DM Shot number 183 Date 12/19/90 Time 16:38

Connection Series with U1 & U2 coils
Mode AC
Description Trapezoid with superimposed ripple

Total inlet flow 17.488 g/s
Inlet pressure 4.995 atm
Inlet temperature 4.351 K

Bm 6.761 T
Tm 1 s
Bm/Tm 6.761 T/s
1/Tm 1.000 1/s
Im 22 kA
Flat top 0.5 s
Im/Tm 22.00 kA/s

Waveform



T1 = 1 s
T2 = 0.5 s
T3 = 0.5 s
T4 = 0.25 s
T5 = 1.25 s

Im = 22 kA
Ia = 80 A
f = 20 Hz

Tm =T1

Quench ? Yes- Coil C crossover turn.

Quench detection sequence
USMC03, USVB5-6,USMC01

Quench time 1.23 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	1.113	—	4.351	4.331	4.790	0.459			
2		—		4.292	5.041	0.749	X		
3 cable	12.566	.705		4.439	5.195	0.756	X		
3 corner		.616		4.221	5.020	0.799	X		
4 corner		.534		5.019	5.520	0.501	X		
4 cable		-.65		6.739	7.910	1.171	X		
5	3.809	—	4.111	5.85	6.775	0.925	X		
6		—		6.4					

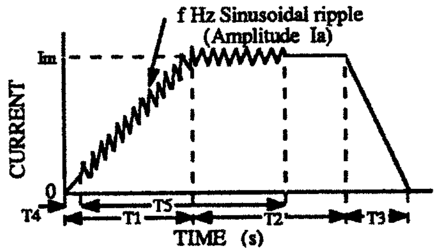
Run number 277 DM Shot number 184 Date 12/19/90 Time 16:50

Connection Series with U1 & U2 coils
Mode AC
Description Trapezoid with superimposed ripple

Total inlet flow 17.744 g/s
Inlet pressure 5.861 atm
Inlet temperature 4.365 K

Bm 6.761 T
Tm 1 s
Bm/Tm 6.761 T/s
1/Tm 1.000 1/s
Im 22 kA
Flat top 0.5 s
Im/Tm 22.00 kA/s

Waveform



T1 = 1 s
T2 = 0.5 s
T3 = 0.5 s
T4 = 0.25 s
T5 = 1.25 s

Im = 22 kA
Ia = 150 A
f = 20 Hz

Tm =T1

Quench ? No

Quench time s

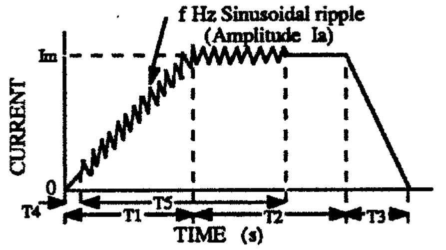
PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]		
	INLET	OUTLET	INLET	OUTLET					
				INITIAL	PEAK	ΔT			
1	1.197	—	4.365	4.344	4.754	0.410			
2		—		4.304	4.980	0.676	154.6		3498.6
3 cable	12.62	.689		4.449	5.110	0.661	159	320	
3 corner		.752		4.231	4.928	0.697	161		
4 corner		.533		5.014	5.512	0.498	51	869	
4 cable		-.62		6.779	7.840	1.061	818		
5	3.927	—	4.125	5.882	6.770	0.888	2155		
6		—		6.4					

Run number	278	DM Shot number	185
Date	12/19/90	Time	17:02

Connection	Series with U1 & U2 coils	Total inlet flow	17.428 g/s
Mode	AC	Inlet pressure	4.995 atm
Description	Trapezoid with superimposed ripple	Inlet temperature	4.365 K

Bm	7.069 T	Im	23 kA
Tm	1 s	Flat top	0.5 s
Bm/Tm	7.069 T/s	Im/Tm	23.00 kA/s
1/Tm	1.000 1/s		

Waveform



T1 = 1 s
T2 = 0.5 s
T3 = 0.5 s
T4 = 0.25 s
T5 = 1.25 s

Im = 23 kA
Ia = 150 A
f = 20 Hz

Tm = T1

Quench ? Yes- Coil C crossover turn and other part.

Quench detection sequence
USMC03, USVB5-6, USMC01

Quench time 1.08 s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]
				OUTLET			
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT	
1	1.183	—	4.365	4.353	4.826	0.473	
2		—		4.306	5.085	0.779	X
3 cable	12.402	.681		4.452	5.225	0.773	X
3 corner		.681		4.234	5.052	0.818	X
4 corner		.611		5.021	5.750	0.729	X
4 cable		-.567		6.775	8.110	1.335	X
5	3.843	—	4.126	5.889	6.820	0.931	X
6		—		X			

Run number	279	DM Shot number	201
Date	12/20/90	Time	10:08

Connection		Total inlet flow	g/s
Mode		Inlet pressure	X atm
Description		Inlet temperature	x K

Bm	T	Im	X kA
Tm	X s	Flat top	s
Bm/Tm	T/s	Im/Tm	kA/s
1/Tm	1/s		

Waveform

Quench ?

Quench time s

PANCAKE	MASS FLOW [g/s]		TEMPERATURE [K]				AC LOSS [J]
				OUTLET			
	INLET	OUTLET	INLET	INITIAL	PEAK	ΔT	
1	X	—	X	4.421			
2		—		4.352			X
3 cable	X	X		4.378			X
3 corner		X		4.166			X
4 corner		X		4.418			X
4 cable		X		4.509			X
5	X	—	X	4.174			X
6		—		6.89			

Runs 279 through 305 were AC tests of the background field coils U1 and U2 with the US-DPC electrically disconnected. The intent of these tests was to collect AC loss data on the US-DPC with no transport current while the background field coils were undergoing a stability investigation by pulsing with various waveforms. However, the helium flow to the US-DPC was too low for the measurement range of the flow meters, and no AC loss data was obtained.