CANFLEX Demonstration Irradiation at Point Lepreau: A Status Update

by:

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Introduction

The Point Lepreau Generating Station (PLGS) is considering changing fuel type from the current, 37-element design to the 43-element CANFLEX design (Figure 1). As part of the preparation for this potential conversion, the station is performing a Demonstration Irradiation of 24 CANFLEX fuel bundles. Conversion to this new fuel type is being considered as part of PLGS' strategy to combat the effect of plant ageing. "Plant ageing" is used to denote a variety of phenomena, such as pressure tube creep and boiler tube fouling, which have the effect of reducing operating margins, particularly on the Regional Overpower Trip system. Since channels containing CANFLEX fuel have enhanced Critical Channel Powers when compared to channels containing 37-element fuel, conversion to CANFLEX could be used to regain operating margins which would otherwise be lost.

The CANFLEX bundle is the latest design in the evolution of CANDU fuel. Its 43-element fuel-bundle assembly and its patented critical-heat-flux enhancement buttons offer higher operating and safety margins, while maintaining full compatibility with operating CANDU reactors. The greater element subdivision and the use of two element diameters lower the peak linear element rating of a CANFLEX bundle compared to the standard 37-element CANDU bundle at the same bundle power. The higher operating and safety margins also offer the potential of reactor power up-rating, which would further increase the economic competitiveness of the CANDU reactor.

CANFLEX development was begun in 1986 by AECL. In 1991, the development effort became a joint effort by Atomic Energy of Canada Ltd. (AECL) and Korea Atomic Research Institute. It has undergone extensive design analysis, performance and qualification testing, as well as an independent review within the Canadian nuclear industry. The design phase is now complete and field commissioning has commenced. The first step of field commissioning is the demonstration irradiation at PLGS. The demonstration irradiation will establish fuel handling and irradiation experience of the CANFLEX bundle in a power reactor, and will confirm the production processes of fuel fabrication for this new bundle design. The demonstration irradiation was planned based on a standardized process which PLGS uses for special fuel irradiations (Reference [1]) Upon successful completion of the demonstration irradiation, the CANFLEX bundle should be a product which is ready for full-scale use in existing and future CANDU reactors.

This paper discusses the channel selection process. It also provides a summary of the information gathered as part of the demonstration irradiation. The paper will present data gathered up to the time of submission and will outline the plans for future data gathering, including the dispositioning of an unusual series of observations during the visual in-bay inspections.

Channel Selection

Channel selection criteria for the CANFLEX DI were derived based on a list of objectives, which are as follows in order of priority:

1. some fuel should be exposed to as high a power as possible within the allowable operating envelope
2. some fuel should be exposed to as wide a power variation as possible within the allowable operating envelope
3. at least one channel should have a normal dwell with a full CANFLEX fuel string
4. some fuel should experience normal fuelling-induced power ramps
5. at least one selected channel shall be in the region of the core in which fuelling is done with the ram extension and one in the region in which it is not required.
6. some fuel should experience the highest burnup which is possible within the allowable operating envelope
7. some fuel should experience the longest time in reactor which is possible within the allowable operating envelope
8. some fuel should be in an instrumented channel

Some of these criteria are mutually exclusive (*i.e.* numbers 1 and 8). Therefore, more than one channel had to be selected for the irradiation. Two channels were sufficient to meet all of the requirements, and that was the selected approach. Therefore, there was a set of selection criteria for each channel. The approach was to define one channel that met the highest possible number of objectives; the second channel was defined to meet the balance of them. If any criteria could be met by both channels, this was done.

Objectives number 1 to 6 can be met by a set of criteria for a single channel. The second channel can then fulfil objectives number 4, 5, 7 & 8. The resulting criteria are:

1. One high-power channel (expectation of a bundle power ≥750 kW) close to the point corresponding to the mid-level of a Liquid Zone Controller (LZC). The channel will receive 2 regular 8-bundle shifts of CANFLEX bundles with a target exit burnup of >160 MW·h/kgU on one CANFLEX bundle.
2. One low-power flow-instrumented channel will be set up, and it will receive one 8-bundle shift of CANFLEX bundles with a target total in-reactor time of about 16 months on the CANFLEX bundles removed in the second shift.

The above criteria were later modified due to the impact of constraints imposed on the channel selection process by the Atomic Energy Control Board (AECB). Most significantly, the AECB required that one of the CANFLEX DI channels be inspected in the 1999 or 2001. Thus a requirement was added that the high-power channel must be one which was inspected in the Fall 1997 outage, so that the inspection results could be interpreted in the light of historical data for the channel. The impact of this additional constraint was that it was not possible for the high-power channel to be near the mid-level of a LZC. More details on channel selection and the overall planning process can be found in Reference [2].

Data Gathering During the Demonstration Irradiation

Reference [3] outlines the information to be gathered during the DI:

1. The date of each CANFLEX fuelling and the channel being fuelled in each fuelling
2. Bundle power-burnup histories as calculated by RFSP for each CANFLEX bundle
3. Reactor power history for the duration of the DI
4. Channel flow indication for the instrumented channel containing CANFLEX fuel for the duration of the DI and for one week thereafter
5. All channel flow measurements for the channels containing CANFLEX fuel from the fuelling flow verification and the quarterly flow verifications
6. DN signal history for the channels containing CANFLEX fuel for the duration of the DI
7. All measurements of PHTS crud levels, pH, dissolved deuterium and dissolved oxygen for the duration of the DI
8. All fuel handling logs for the fuelling visits to CANFLEX-fuelled channels for the duration of the DI
9. Events or unusual alignments affecting the PHTS
10. Any fuel handling events affecting CANFLEX bundles
11. The results of the visual in-bay inspections

The low power, instrumented channel selected for the DI was channel Q20. It was fuelled with CANFLEX on September 3 1998. On March 26 1999, 8 bundles were discharged from Q20, including 4 CANFLEX bundles. 4 more CANFLEX bundles remain in the channel. The high power channel selected for the DI was channel S08. It was fuelled with CANFLEX on September 6 1998 and then again on August 8, 1999. The serial numbers of the CANFLEX bundles fuelled in the demonstration irradiation are shown in Table 1.

A selection of the data which have been collected with respect to the CANFLEX irradiation in these two channels are presented here. Note that no detailed data analysis has been performed - this data has been gathered in order to create an archive which can be "mined," if necessary, to assess more details of the fuel performance. The data are presented in this paper to indicate what sort of information is available.

Table 2 shows the measured channel pressure drop before and after fuelling for a series of fuellings which includes the September 1998 fuellings of Q20 and S08. The table shows that the change in pressure drop due to fuelling with CANFLEX is not drastically different than has been observed for 37-element fuellings.

Figure 2 shows the channel outlet temperatures as indicated by the RTDs for the CANFLEX channels for each CANFLEX fuelling thus far in the DI.

Figure 3 shows the indications of instrumented channel flow in channel Q20 for the duration of the DI. As expected, the flow is not discernibly different than what would be expected for a channel full of 37-element fuel.

Figure 4 shows the bundle power history for the highest power CANFLEX bundle yet discharged, from RFSP, corrected for reactor power. This is bundle 6 of channel S08. Note that the bundle power originally reported by RFSP is the power which the bundle would achieve if the reactor were operating at full power. For most of the DI, PLGS has operated a few percent below 100% full power (at ~97% full power), and the data as presented have been corrected to account for this. The peak bundle power achieved was 773 kW. Bundle 7 of this channel has a very similar power history. The data show that CANFLEX fuel has achieved high bundle powers during the DI.

Figure 5 and Figure 6 show photographs taken by R. G. Steed during visual in-bay inspection of the CANFLEX fuel bundles discharged from channel Q20. Apart from some minor deformation to both end plates of all four bundles, fuel bundles examined to date appear entirely healthy. This deformation is evident at both ends of a single element or pair of elements, and consists of shallow grooves or gouges in the circumferential surface of the end plate. This deformation was not seen on a 37-element bundle discharged with the CANFLEX bundles. While the marks are not serious (less that 50 μm deep), and the endplates still met the requirements of the relevant technical specification, they were not usual based upon previous experience at PLGS and they were investigated.

Examination of the unirradiated fuel bundles in the new fuel room showed that the same markings were present on them. Investigation by the manufacturer indicated that the manufacturing process applied to the CANFLEX endplates (which differed from the normal punch and die method applied to endplates of 37-element fuel due to the small quantities involved) resulted in these minor marks around the perimeter of the endplate. It should be re-emphasized that the endplates still met all relevant design specifications. Such markings would not be expected on a full scale production run of CANFLEX fuel bundles, as their endplates would be stamped as is the case for 37-element fuel.

References

1 P. J. Reid, R. G. Steed, R. A. Gibb, R. W. Sancton, "A Standard Approach to Special Fuel Irradiations at Point Lepreau Generating Station", Proceedings of the 19th Annual Conference of the Canadian Nuclear Society, 1998

2 R. A. Gibb, R. W. Sancton, D. C. Taylor, R. G. Steed, P. J. Reid, J. Bullerwell, "CANFLEX Demonstration Irradiation at Point Lepreau: Background and Observations", presented at the 20th Annual Conference of the Canadian Nuclear Society, 1999

3 P. J. Reid, "CANFLEX Demonstration Irradiation: Background and Technical Basis", PLGS IR-37600-01, March 5 1998

Table 1: CANFLEX Bundles Fuelled in the Demonstration Irradiation

(a) Channel Q20W

Position	Bundle Serial #
1	FLX020Z
2	FLX026Z
3	FLX021Z
4	FLX022Z
5	FLX019Z
6	FLX025Z
7	FLX023Z
8	FLX024Z

(b) Channel S08W (first fuelling)

Position	Bundle Serial #
1	FLX014Z
2	FLX013Z
3	FLX015Z
4	FLX016Z
5	FLX017Z
6	FLX018Z
7	FLX008Z
8	FLX007Z

(c) Channel S08W (second fuelling)

Position	Bundle Serial #
1	FLX009Z
2	FLX010Z
3	FLX011Z
4	FLX012Z
5	FLX006Z
6	FLX005Z
7	FLX004Z
8	FLX003Z

Table 2: Fuelling Machine ΔP (kPa) for Fuellings in CANFLEX DI Channels

(a) Channel Q20W

Date	ΔP1	ΔP2	ΔP1 – ΔP2
26/03/99	359	365	6
03/09/98	352	355	3
11/09/97	374	381	7
02/07/96	343	357	14
05/03/95	372	374	2
20/06/94	344	354	10
26/10/93	-359	-363	-4
25/02/93	367	355	-12
29/06/92	387	387	0
29/08/91	369	371	2

(b) Channel S08W

Date	ΔP1	ΔP2	ΔP1 – ΔP2
08/08/99	619	633	14
06/09/98	610	613	3
11/03/98	563	581	18
19/01/97	0	0	0
31/10/96	703	701	-2
03/04/96	616	630	14
03/02/95	618	605	-13
11/08/94	585	578	-7
31/01/94	583	587	4
03/08/93	-622	-636	-14

Figure 1: CANFLEX 43-Element Bundle

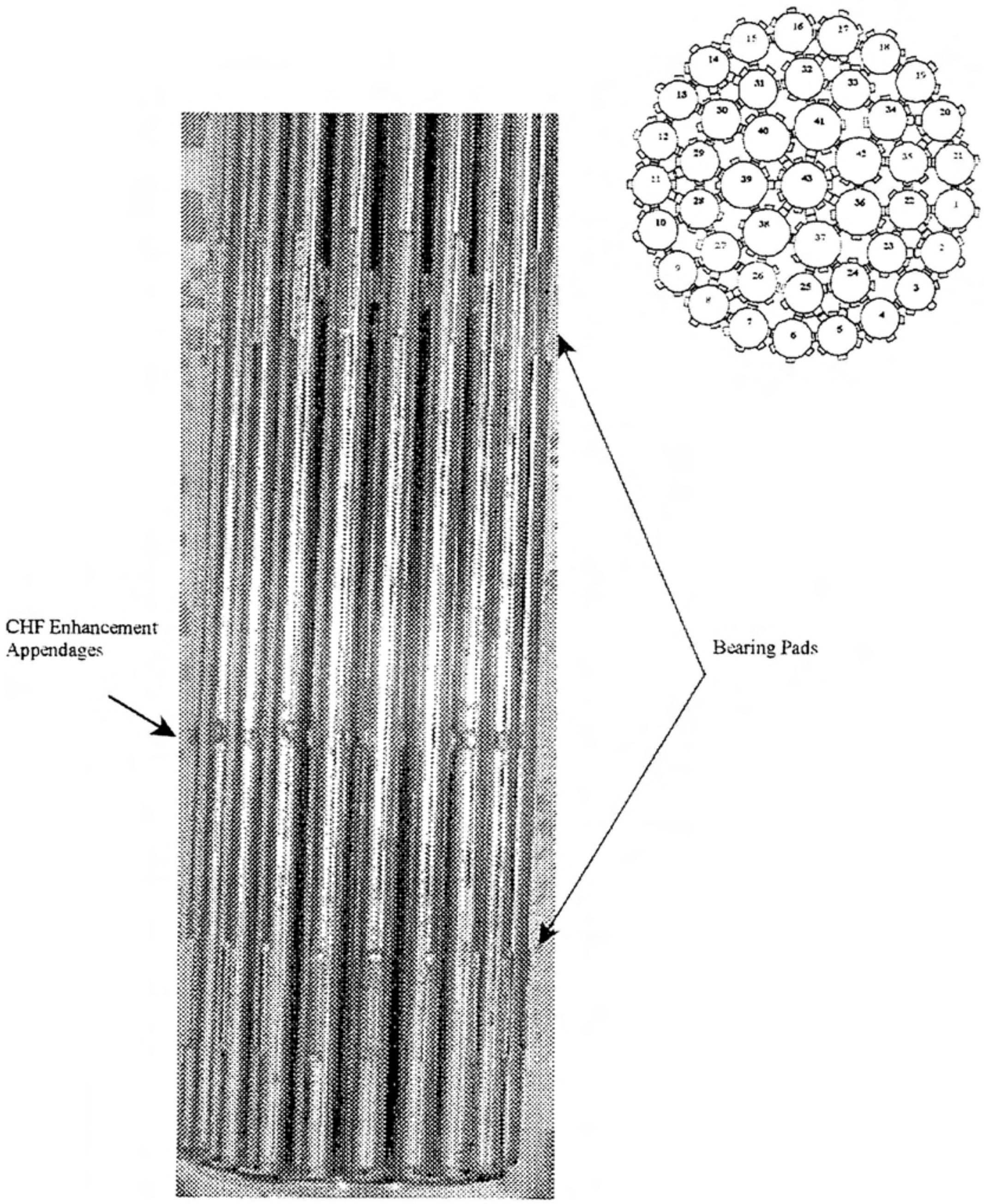


Figure 2: Channel RTD Data from CANFLEX Channels for Fuellings During DI

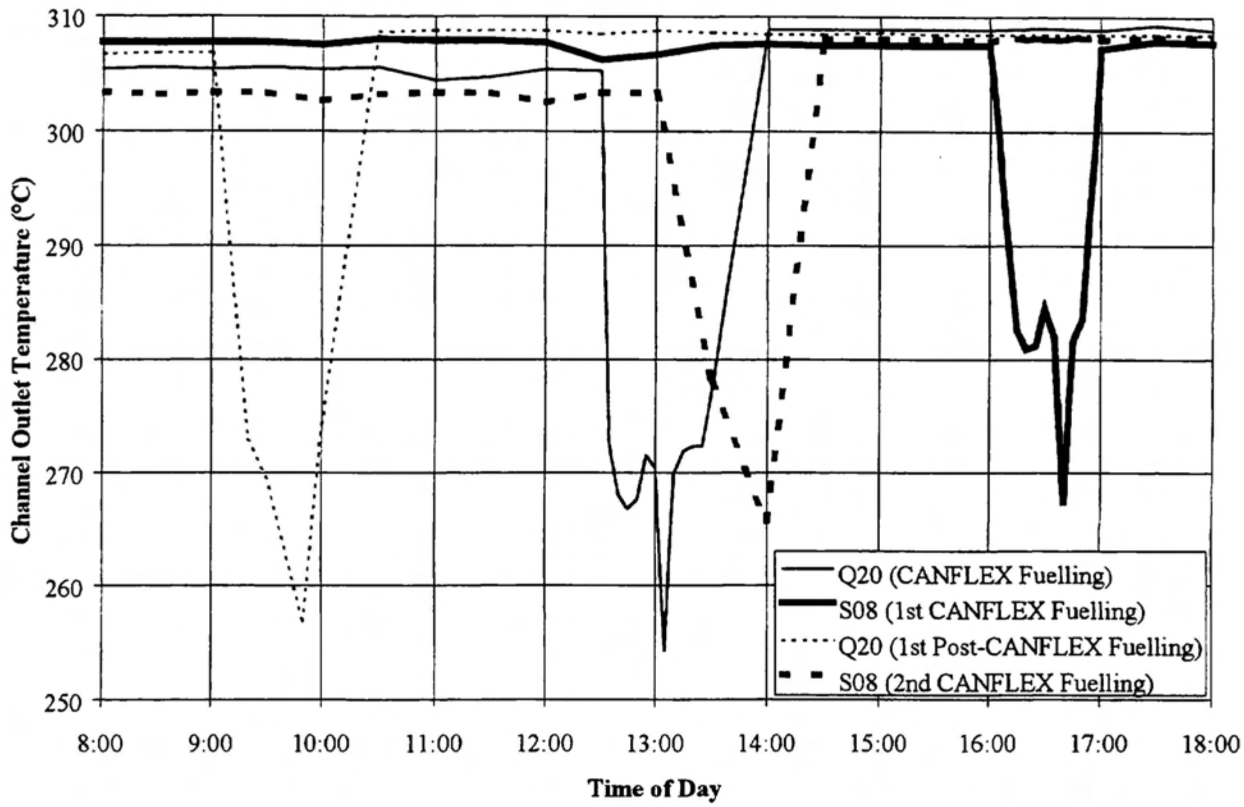


Figure 3: Channel Q20 Indicated Flow During DI (Raw Data)

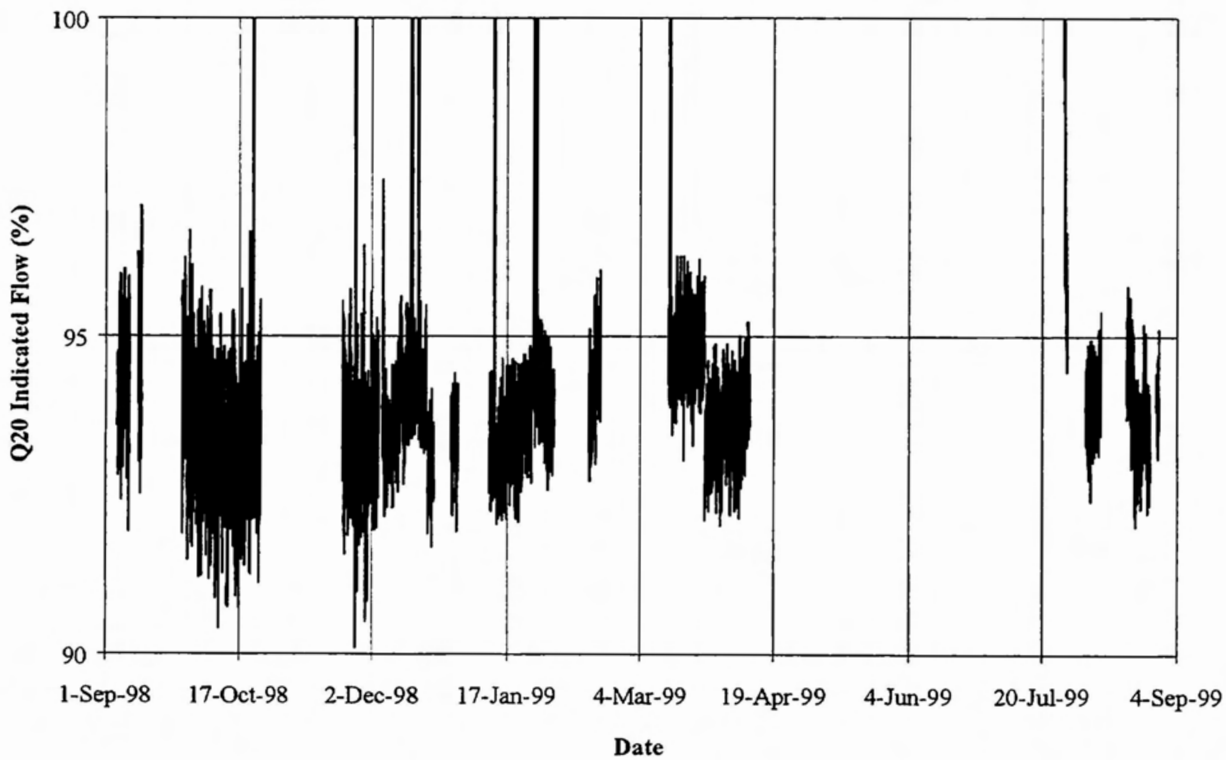


Figure 4: Complete Bundle Power History for Bundle FLX018Z (S08W, Bundle 6)

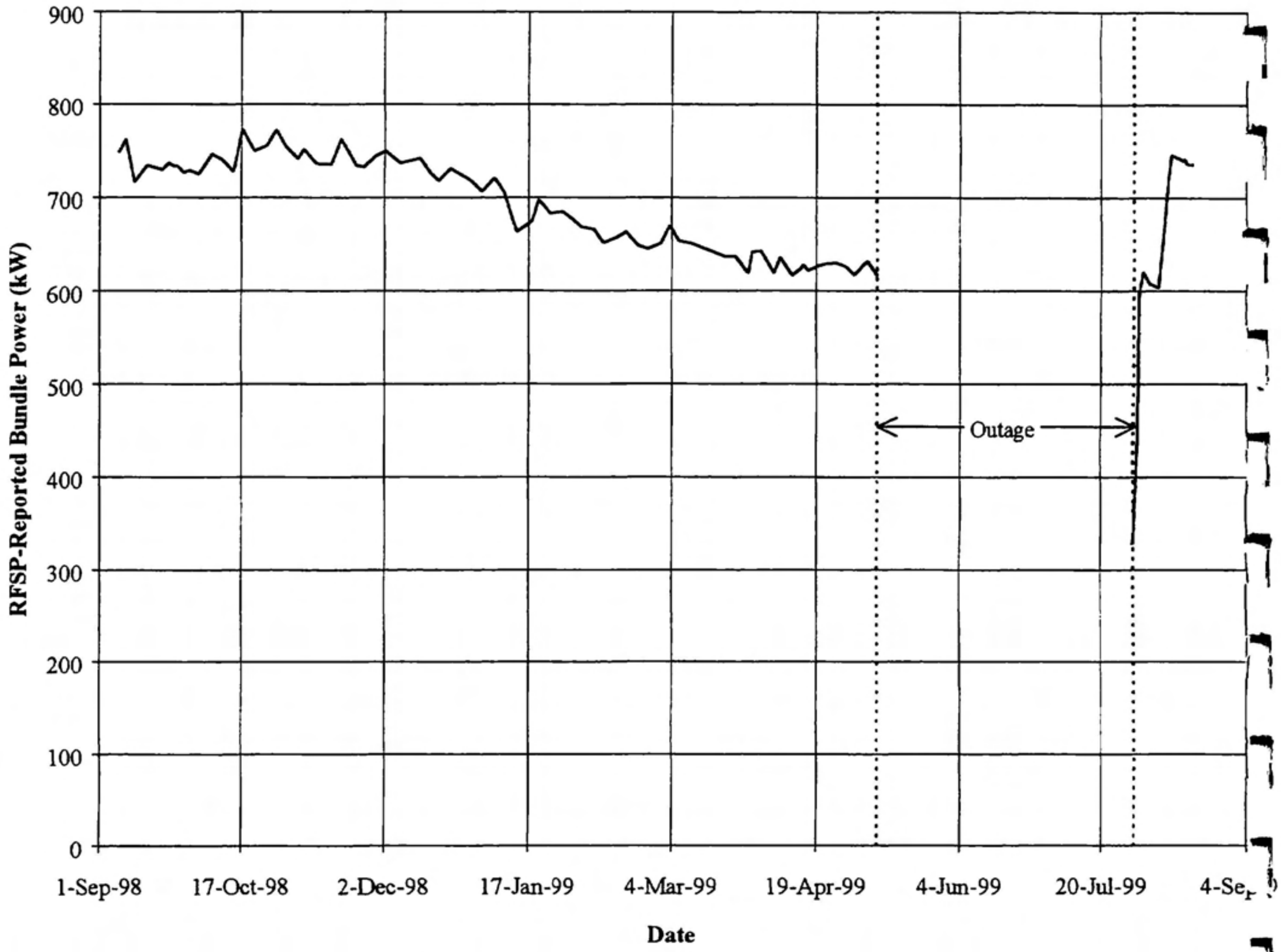
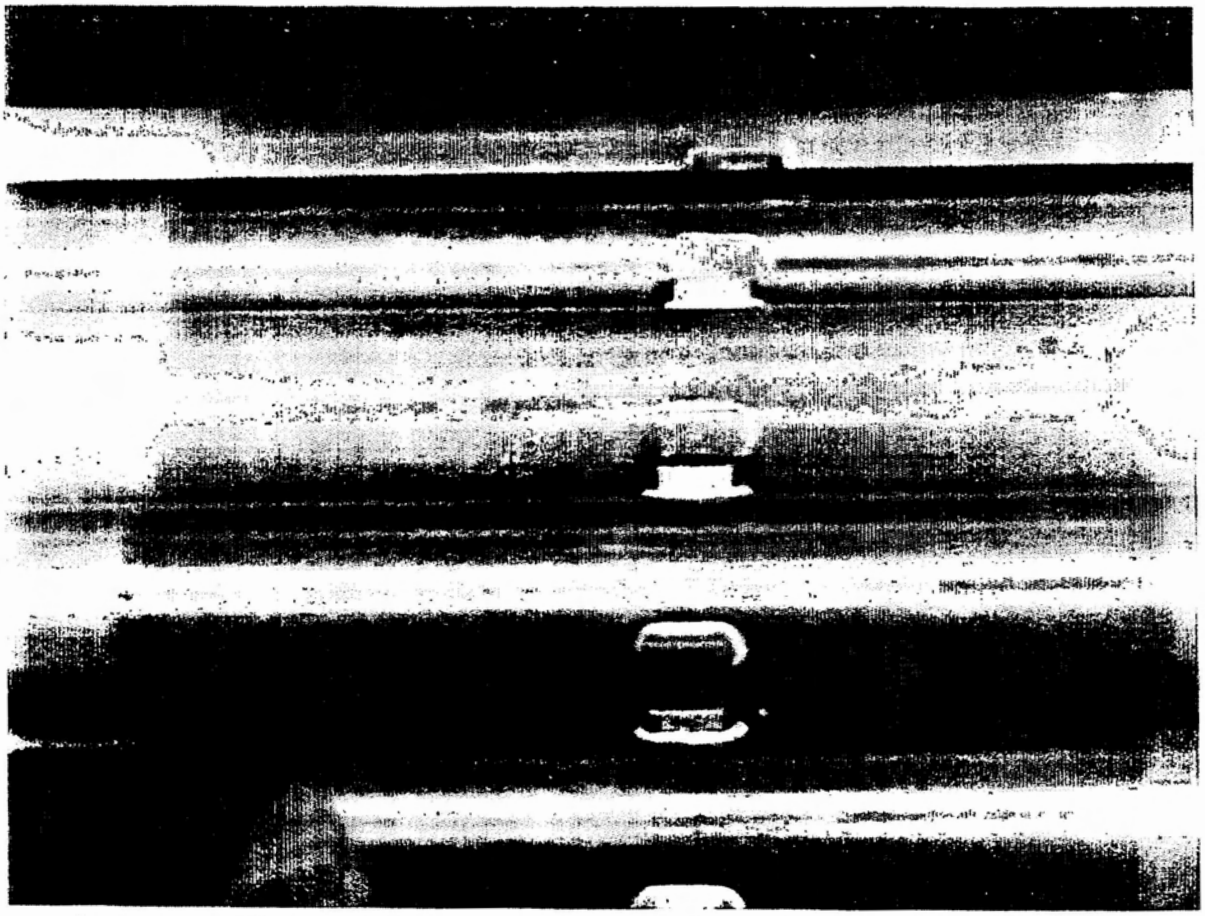


Figure 5: Photo of Bundle FLX025Z

R. G. Steed photo



CANFLEX FLX025Z

Figure 6: Bundle FLX019Z, Showing Deformation

R. G. Steed photo