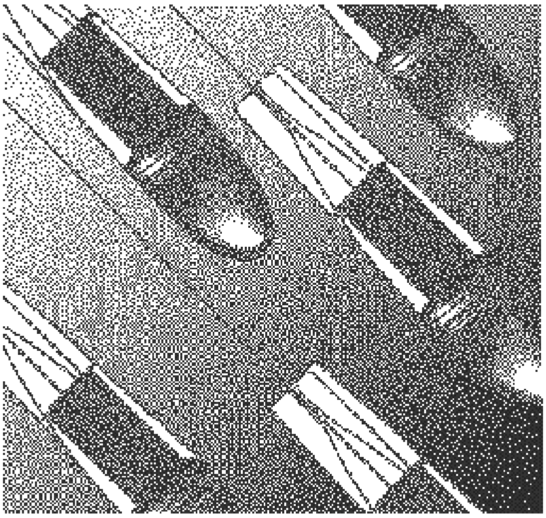
CSIRO Marine Laboratories Report 221

Quality Control Cookbook for XBT Data*
(* Expendable Bathythermograph Data)

Version 1.1

R. Bailey, A. Gronell, H. Phillips, E. Tanner, and G.Meyers



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Abstract

Expendable Bathythermographs (XBTs) have been used for many years by oceanographers to measure the temperature of the upper ocean. These instruments are simple devices which are designed to be deployed from moving vessels, enabling broad scale coverage of the world's oceans. The XBT has accordingly played an important role in several large international research programs, and the global data archives reflect this. Quality Control (QC) procedures are described for data recorded by XBTs. Examples are shown and described for

commonly observed oceanographic features and instrument malfunctions. A QC code (flagging) system is described, which aids in the process of future validation and documentation of real features, and in the elimination of erroneous temperature profiles. There are some modes of malfunction of the XBT which appear very similar to real oceanographic features. This "Cookbook" enables the user to better distinguish between the two. A knowledge of the different types of real and erroneous features, when combined with a local knowledge of water mass structure, statistics of data anomalies, the depth and gradient of the thermocline, and cross validation with climatological data in a statistical sense, ensures a data set of the best possible quality.

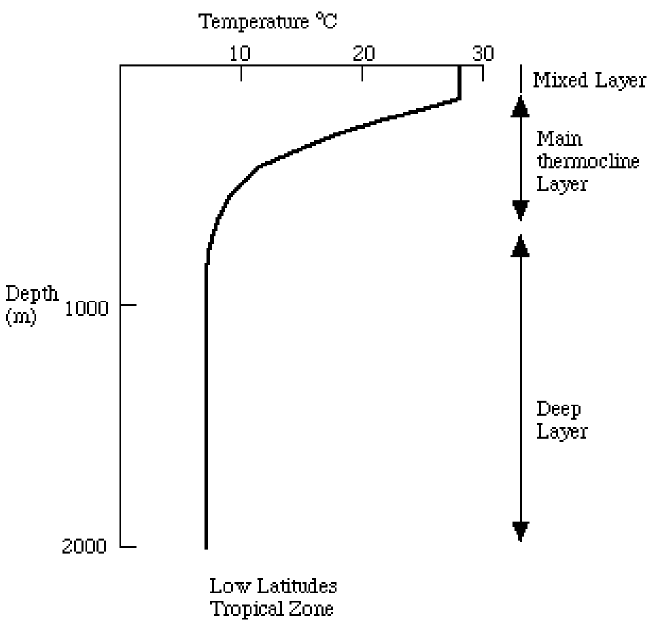
Introduction

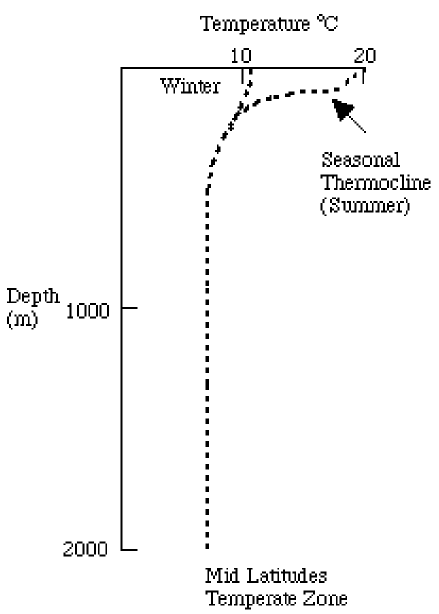
The Quality Control (QC) procedures described here have been developed by oceanographers participating in the CSIRO XBT Program, specifically to assure the research quality of expendable bathythermograph (XBT) data of 0.6 to 2.0 m resolution, at the delayed mode stage. This manual provides an overview of real oceanographic features and instrument errors that have been monitored over a period of years and from which the CSIRO procedures and QC codes (flags) have been developed. An example of each flag is provided to illustrate the subtle differences in structure that occur when either an error or feature is recorded in the XBT profile data. We believe that checking XBT data for the occurrence of these errors and features, combined with comparisons to climatological data and to neighbouring profile data, forms the basis of scientific quality control.

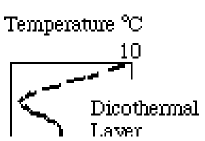
The ability to judge whether a feature is realistic for a particular region cannot easily be passed on to a QC operator from a manual such as this. Local knowledge of water mass structure, statistics of data anomalies, the depth and gradient of the thermocline, as well as reference material from atlas data must be incorporated into the validation process. These ingredients all help to establish if the specific event (e.g., an inversion) identified in the profile is probable or not for the region in which it was observed.

The potential types of malfunctions of the XBT instrument must also be kept in mind when performing QC. If uncertain, the QC operator should proceed with caution whilst ensuring that no good data is thrown away. The type of flag to assign under these circumstances will depend on the type of error or feature, and the appropriate action to take will become clearer as each flag is discussed in detail. This "cookbook" is intended to make the identification of real and erroneous features easier. It must be kept in mind, however, that the ability to make valid scientific QC decisions requires training under expert supervision.

These procedures can also be applied to low to medium resolution, inflection point XBT data. However, the lower resolution makes it more difficult to identify the structures described here.







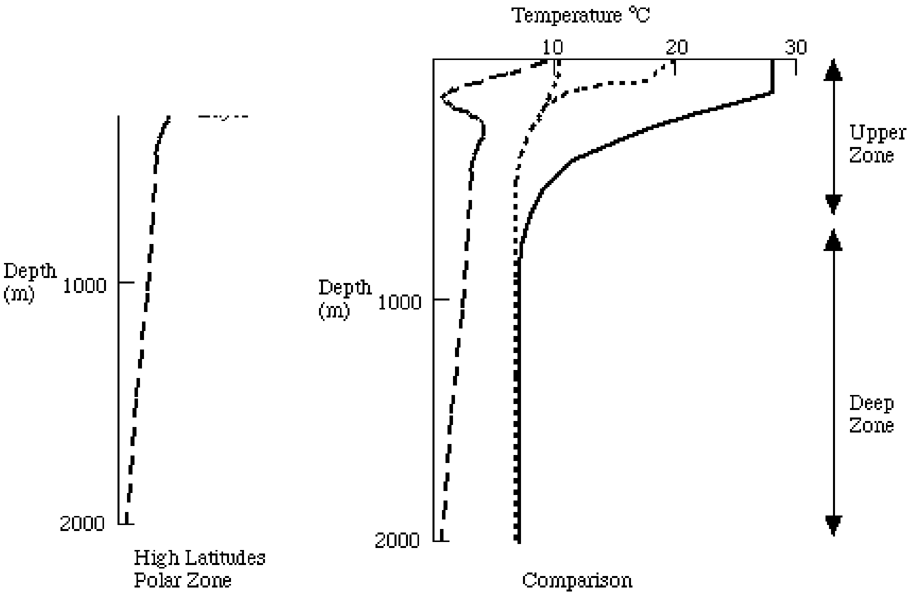


Figure 1. Typical mean temperature / depth profiles for the open ocean.
(Adapted from Pickard and Emery, 1990)

Temperature Structure in the Oceans

The vertical temperature structure in the ocean is generally divided into three zones. There is an upper mixed layer with fairly uniform temperatures similar to those at the sea surface. The thermocline is the zone below the mixed layer in which the temperature gradient (rate of change of temperature with depth) is at a maximum. Below the thermocline is a deep zone in which temperature changes slowly. The depths of these features vary with time and geographic location. Some typical XBT profiles are depicted in Figure 1.

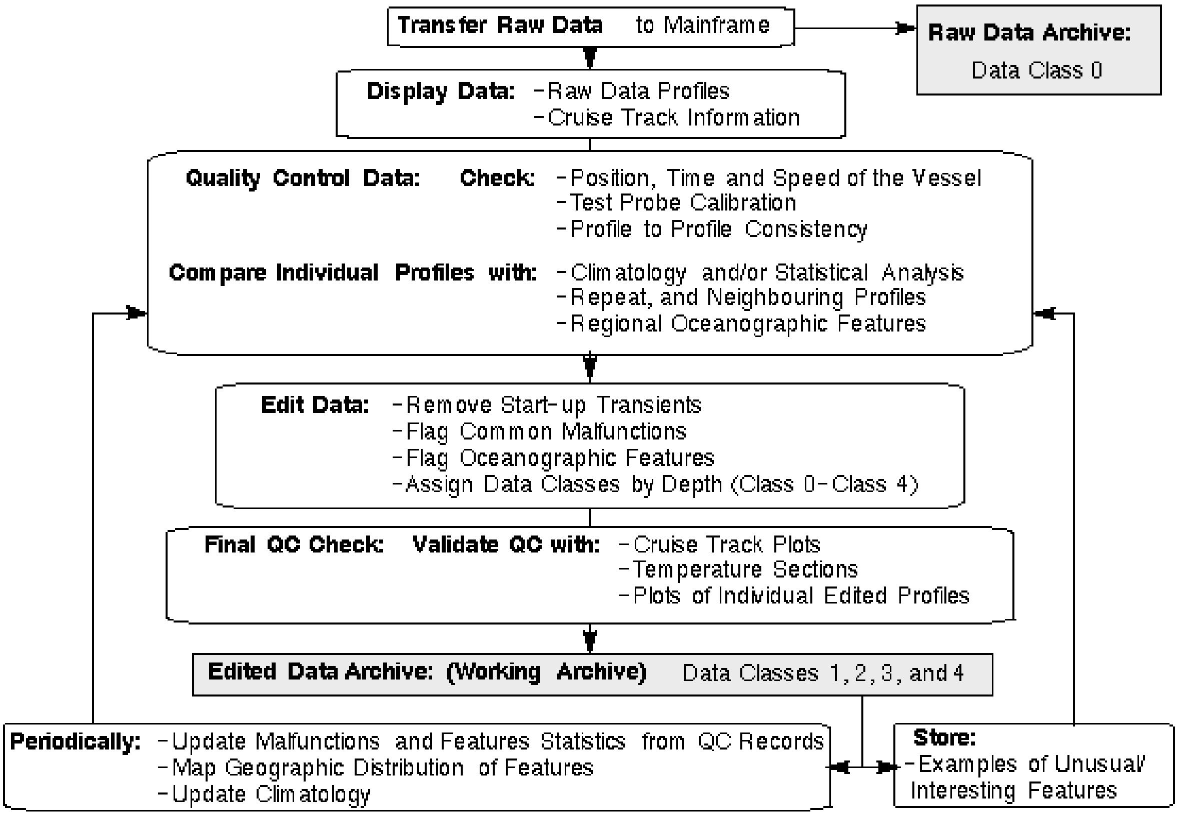
Sea surface temperatures in the open ocean generally vary between a maximum of 30°C near the equator to a minimum of -1.9°C (freezing temperature of seawater) at high latitudes. The temperature at the sea surface is often representative of the temperature over a range of depths that are well mixed by wind and wave action. Heat is transferred downwards to the deeper layers by the action of turbulence. A high degree of vertical uniformity with little variation in temperature, salinity, or density is therefore often observed in the upper layer.

The surface mixed layer exhibits characteristic seasonal (especially in the mid and high latitudes) and regional variations in response to the local climatic conditions; and the depth of the mixed layer varies accordingly. During winter the mixed layer depth is enhanced by cooling from the surface and by strong wind and wave action. During summer, the winds are generally lighter and the mixed layer does not usually extend as far. Generally the mixed layer is between 50-100 m thick in low latitudes and 25-250 m (extending to the permanent thermocline) in mid latitudes. In high latitudes a near constant temperature profile can sometimes be observed over hundreds of metres depth.

Seasonal effects are limited to a narrow range of depths in the ocean by the extent of vertical mixing. A ìseasonalî thermocline may develop in some regions (mid and high-latitudes) from the surface to about 200 m depth in response to heating by the atmosphere. Summer warming accentuates the thermocline by diminishing the density of the surface layers, while winter cooling erodes the thermocline and establishes the mixed layer. The depth range from below the seasonal thermocline to about 1000 m is known as the ìpermanentî or oceanic thermocline. This is the transition zone from the warm waters of the surface layer to the cold waters in the deep ocean. The ìpermanentî thermocline is consistently present extending from 100ñ1000 m depth at low latitudes and from 200ñ1000 m at mid latitudes. However, no permanent thermocline is established at high latitudes (polar regions).

Although the temperature in the upper zone shows seasonal and regional variations in response to the local climatic conditions, the deep zone remains fairly constant in both these respects with a well defined temperature-salinity relationship. Most types of XBT are designed to measure the vertical temperature structure in the top 450 m to 750 m of the water column so they do not generally extend far into the deep zone.

Apart from the mixed layer and thermocline, many other subtle changes in the ocean's vertical temperature structure may also be observed in an XBT temperature profile by a trained observer. Different types of fine structure associated with intrusions, convection or turbulent mixing events, on vertical scales of tens of centimeters to hundreds of meters, can often be picked up in an XBT profile, or series of profiles. Temperature inversions are often observed as an increase of temperature with depth in a profile and occur in regions of the ocean in which the local conditions favour their formation (e.g. inversions in the mixed layer are sometimes observed in the tropics). Other meso-scale ocean features such as eddies, fronts or convergence zones, may be pin-pointed by large temperature differences over a large depth range from one profile to another.



Overview of Quality Control Procedures

The CSIRO XBT Quality Control process uses a visual approach combined with an interactive editor to check and flag the data. The header information is tested for correct time, position and other operator errors. The vertical profiles are inspected for common malfunctions, regional oceanographic features, drop to drop consistency along the cruise track, and repeat drops of unusual features. Features may be further checked with CTD data as opportunities arise. Figure 2 shows the steps involved in the CSIRO quality control process. All unedited/raw data is stored in a separate archive for future reference if required.

The Header information is assessed first, as the detection of these errors is more straightforward than for the profile data. Errors detected in the time and position fields are corrected if possible; however, if these cannot be resolved with a reasonably high degree of confidence the vertical profile data is considered unusable as it cannot be properly referenced. The original position of XBTs deployed during a voyage are viewed in the form of a cruise track plot. This is done for verification of the profile positions before individual profile plots are examined. A program is then run to verify the position, time and speed of the vessel along the cruise track. The test probe information is checked to ensure the integrity of the measuring equipment.

Once the header information has been validated, the individual profile plots are inspected for common malfunctions, regional oceanographic features and profile to profile consistency. Unusual features are cross validated by comparison with repeat or neighbouring profiles, and by using an archive of previously observed oceanographic features in particular regions. Doubtful features can appear and be flagged at any point in the profile. If anomalous features are present, the operator should question the validity of the profile(s) and when in doubt always look at a repeat or neighbouring drop for confirmation. A repeat drop is an XBT that has been done within 15 minutes (or 10 km) of another drop and a neighbouring drop is an XBT that is within 100 km of another drop. Care must be taken in labeling features as doubtful, since variations in thermal structure do exist, particularly in regions of oceanic fronts and eddies. Variations can also occur in less dynamic regions. Checking profiles with repeat or neighbouring drops and against an archive of regionally observed oceanographic features should be done on a regular basis. All profiles are also checked against Levitus climatology (Levitus, 1982) and/or a climatology that has been constructed from the CSIRO archive of XBT data.

The profile data is then edited to remove start-up transients (see section 2.1) and other malfunctions, and to flag real oceanographic features. Depending on the severity of the problem, the data quality may be downgraded. The XBT profile data are classed (0-4) by depth according to the type of quality control flag(s) associated with the data. The grading system is outlined in Table 1, "Data Quality Classes". All modifications that are made to the data are reflected in coded quality flags. Anomalous features present within the profile data are flagged to indicate whether the feature is a real or probable oceanographic feature, or whether it is a possible or definite malfunction. Table 2, "Summary of CSIRO Quality Control Codes" outlines the codes (flags) which may be assigned to features and malfunctions observed in the XBT data during the CSIRO quality control process. Results of the profile QC process are recorded and stored in association with each temperature/depth pair.

Since there are real oceanographic features and XBT malfunctions which may appear very similar to each other, a decision must be made about which QC flag to use. There are two general types of flag that can be applied: an accept flag and a reject flag. The accept flag is used in instances where you can be sure that the feature is real, or if a malfunction is thought to result in minimal impact on the quality of the data. If there is doubt about the feature, or the impact to the quality of the data is severe, then the reject flag is used. Inflection point data (including BATHY messages) must be quality controlled with a certain amount of caution as these data are of lower resolution. Many of the subtle features that are identified in this cookbook will not be encoded in the message, and therefore may be difficult to detect.

Automated programs are used to aid in the process of detecting position and timing errors that are allocated flags from the header information category. However, detection and flagging of the profile data requires careful attention and experience as many of the instrument errors may look like real features to the untrained eye. For example, a temperature inversion and a wire stretch both exhibit an increase in temperature with depth when observed in an XBT profile. There can sometimes be a variety of errors and oceanographic features recorded within the profile structure. The profile feature/error flags are assigned according to the following categories; general flags, inversions/wire stretch, structure/leakage or eddy, front or current/temperature offsets.

The detailed explanation of these codes is the subject of the remainder of this manual and should help facilitate and standardize the process of scientific quality control. The codes have been designed to be used as a research tool as well as quality control indicators, such that when the occurrences of flags are mapped, we can build an understanding of regional variations in features of interest. This can then be used to better determine whether an apparent feature is scientifically probable for a certain area. If in doubt about applying an accept or reject flag to the profile, the QC operator should take a conservative approach and use the flag that results in the lower class of data. The classes have been constructed to be sufficiently flexible so that good data will rarely be discarded if this method is followed.

Table 1. Data Quality Classes

Class	**Quality**	**Description**
Class 0	No QC done	Class 0 data are the level at which all data enter the working archive. They have not yet been quality controlled.
Class 1	Good data	Class 1 data are top quality data in which no malfunctions have been identified and all real features have been verified during the quality control process.
Class 2	"Probably" good data	Class 2 data are good data in which some features (probably real) are present but these are unconfirmed. Class 2 data are also data in which minor malfunctions may be present but these errors are small and/or can be successfully corrected without seriously affecting the overall quality of the data. Data are downgraded to Class 2 from the depth of anomalous (probably real) features.

Class 3	"Probably" bad data	Class 3 data are suspect data in which unusual, and probably erroneous features are observed, Data are downgraded to Class 3 and rejected (may be retrieved) from the working archive from the depth of the anomalous (probably erroneous) features.
Class 4	Bad data	Class 4 data are data in which obviously erroneous values are observed. Data are downgraded to Class 4 from the depth of the erroneous features.
Class 5	Changed	Class 5 data are values that have been changed as a result of quality control. The original values (before the change) are preserved.

Table 2. Summary of CSIRO Quality Control Codes

Ref. No.	Catagory	Accept Code	Action	Quality Class	Reject Code	Action	Quality Class
1. Header Information Flags							
1.1	Position Error	PEA	Manually correct.	Class 2 from the surface.	PER	Reject data from working archive.	Class 3 from the surface.
1.2	Time Error	TEA	Manually correct.	Class 2 from the surface.	TER	Reject data from working archive.	Class 3 from the surface.
1.3	Other/ Probe Error	OPA	Manually correct.	Class 2 from the surface.	OPR	Reject data from working archive.	Class 3 from the surface.
1.4	Repeat Drop	REA	Flag as a repeat drop	Class 1 from the surface.	RER	Bad repeat drop to be rejected from working archive.	Class 3 from the surface.
1.5	Duplicate Drop	DUA	Flag as a duplicate drop	Class 1 from the surface.	DUR	Inferior or exact copy to be rejected from working archive.	Class 3 from the surface.

Ref. No.	Catagory	Accept Code	Action	Quality Class	Reject Code	Action	Quality Class
2. Recorder Flags							
2.1	Surface Spikes (Start-up Transient)	CSA	Remove all surface data to 3.9 m depth.	Class 1 from the surface.	CSR	Reject data from working archive.	Class 3 from the surface.
2.2	Test Probe	N/A	-	-	TPR	Reject test data on all occasions from working archive.	Class 4 from the surface.

2.3	Bathy Systems Software Fault (Modulo 10 Spikes)	MOA	Replace Spikes with linearly interpolated values.	Class 2 from the surface.	MOR	Reject data from working archive.	Class 3 from the surface.
2.4	PROTECNO Systems Leakage (PET Fault)	PFA	Downgrade data from depth of anomaly.	Class 2 from depth of anomaly.	PFR	Delete data from depth of anomaly from working archive.	Class 3 from depth of PET fault.
2.5	Bathy Systems Leakage (Cusping)	CUA	Downgrade data from depth of anomaly.	Class 2 from depth of cusping.	CUR	Reject data from depth of anomaly from working archive.	Class 3 from depth of cusping.
2.6	Bathy Systems Bowing (Bowed Mixed Layer)	BOA	Downgrade data from the surface.	Class 2 from the surface.	BOR	Reject data from working archive.	Class 3 from the surface.
2.7	Sippican MK-9 Processor Malfunction (Sticking Bit Problem)	SBA	Apply a 19 point filter with coefficients of 0.0562 and down-grade.	Class 2 from the surface.	SBR	Reject data from working archive.	Class 3 from the surface.
2.8	Sippican MK-9 Timing Delay Problem (Driver Error)	DRA	Downgrade data from the surface.	Class 2 from the surface.	DRR	Reject data from working archive.	Class 3 from the surface.
Ref. No.	**Catagory**	**Accept Code**	**Action**	**Quality Class**	**Reject Code**	**Action**	**Quality Class**

3. General Profile Flags

3.1	Hit Bottom	HBA	Flag data from depth of anomaly from working archive.	Class 2 from depth of possible isothermal boundary layer.	HBR	Reject data from depth of anomaly from working archive.	Class 3 from depth of hit bottom event.
3.2	Wire Break	N/A	-	-	WBR	Delete data from depth of anomaly from working archive.	Class 4 from depth of wire break.
3.3	Spike	SPA	Remove erroneous data and linearly inter-polate. Downgrade from depth of anomaly	Class 2 from depth of spike.	SPR	Delete data from depth of anomaly from working archive.	Class 4 from depth of spike.
3.4	High Frequency Interference	HFA	Filter Noisy Data. Downgrade from depth of anomaly	Class 2 from depth of high frequency interference	HFR	Reject data from depth of anomaly from working archive.	Class 3 from start depth of interference
3.5	Insulation Penetration	IPA	Replace spike with linearly interpolated data.Downgrade from depth of anomaly	Class 2 from depth of spike.	IPR	Reject data from depth of anomaly from working archive.	Class 3 from depth of spike.
3.6	Constant Temperature Profile	CTA	Keep profile to 10 metres depth and flag CTR below 10 metres depth.	Class 1 to 10 metres, Class 3 below.	CTR	Reject data from the depth of the anomaly from working archive.	Class 3 from the depth of the anomaly.
3.7	No Trace	-	-	-	NTR	Delete data from the surface from working archive.	Class 4 from the surface.
3.8	No Good Profile	-	-	-	NGR	Delete data from depth of anomaly from working archive.	Class 4 from depth of anomaly.

4. Inversion/ Wire Stretch Flags

4.1	Inversion (Confirmed)	IVA	Verify inversion in neighbours and repeat drops.	Class 1 from the surface.	-	-	-
4.2	Inversion in mixed layer (Nub Confirmed)	NUA	Verify nub in neigh- bours and repeat drops.	Class 1 from the surface.	-	-	-
4.3	Inversion (Probable)	PIA	Check for similar fea- tures in neighbouring drops.	Class 2 from depth of probable inversion	-	-	-
4.4	Wire Stretch (Possible)	WSA	Check if similar features are observed in neighbouring drops. Downgrade data	Class 2 from depth of possible wire stretch	-	-	-
4.5	Wire Stretch	-	-	-	WSR	Reject data from depth of anomaly from working archive.	Class 3 below depth of wire stetch.

5. Structure/ Signal Leakage Flags

5.1 a	Fine Structure Step-Like (Confirmed)	STA	Verify step-like fine structure in neighbours (usually repeat) drops.	Class 1 from the surface.	-	-	-
5.1 b	Fine Structure Step-Like (Probable)	PSA	Check for step-like fine structure in neighbours and downgrade.	Class 2 from the surface.	-	-	-
5.2	Surface Anomaly (Fine Structure Special Case)	SAA	Check for evidence of surface anomalies in the region and downgrade.	Class 2 from the surface.			
5.3	Fine Structure (Probable)	FSA	Check for fine structure in neighbours and downgrade.	Class 2 from the surface.	-	-	-
5.4	Leakage (Possible)	LEA	Check if similar anomalies are observed in neighbours and downgrade.	Class 2 from the surface.	-	-	-
5.5	Leakage				LER	Reject data from depth of anomaly from working archive.	Class 3 below depth of leakage.

6. Eddy-Front/ Temperature Offset Flags

6.1	Eddy / Front	EFA	Verify eddy / front in repeat or neighbouring drops.	Class 1 from the surface.	-	-	-
6.2	Temperature Dif- ference at Depth	TDA	Check for divergence of temperature at depth in comparison with neighbouring drops.	Class 2 from the depth of the temperature divergence.	-	-	-
6.3	Temperature Offset	-	-		TOR	Check neighbouring profiles for temperature differences. Reject data from working archive.	Class 3 from the depth of the temperature offset.

7. Quality Control Check Flag							
7.1	Quality Control Check	QCA	Indicates that Quality Control has been performed on a particular drop.	Class 1 from the surface.	-	-	-

Quality Control Flags

The temperature profile data represents the most challenging and interesting aspect of the quality control of XBT data. When an XBT probe is launched, the data recording cycle is triggered by contact of the sea electrode with the sea surface. Data recording continues for a time period corresponding to the probe's rated depth. As the probe descends through the water column, insulated copper wire is unreeled simultaneously from the probe spool and from the canister spool in the XBT launcher. This wire provides a sensor line from the probe to the computer on board the vessel. Temperature changes in the surrounding water, measured as change in electrical resistance, are generally recorded in the bridge circuit at a rate of 10 Hz (~65 cm depth intervals) and a resolution of ± 0.01°C. The water depth is not sensed directly by the probe but calculated from the time elapsed since probe contact with the water and the probe's expected fall rate. The XBT probe accuracy is rated to ± 0.15°C so that noise of this order or smaller can usually be ignored.

Many types of malfunctions can cause erroneous temperature readings in the temperature profile. The faults may be restricted to a spike in a single recorded temperature value, or may effect the temperature over a range of depths. The errors may have a high wave-number/jittery appearance or may be smooth features over 10's of metres. Some of these malfunctions produce temperature errors that resemble real features such as temperature inversions or fronts. Many of the profiles can be "cleaned up" by deleting or filtering a portion of the original data. For example, high frequency noise caused by radio interference, which is observed as regularly spaced and symmetric oscillations, can often be filtered to reveal a smooth undisturbed profile, even if of large amplitude (>5°C). The data will be flagged as having been filtered and downgraded to "Class 2"; from the depth of filtering to indicate that changes have been made to the original data. Sometimes the data cannot be recovered after instrument malfunctions and the data from the depth of the malfunction is downgraded to either "Class 3" or"Class 4".

1. Header Information Flags

The QC flags in the Header Information category are concerned with the correctness of the time, position and probe type identifier fields contained in the Header of the XBT record. All the data for one voyage are assembled, ordered by time/date and a speed check program is executed to verify that the ship is travelling at a valid speed (0 to 25 knots). Any observations that fail this test are first identified, and then manually corrected (if possible), and assigned the appropriate flag to indicate what action was taken, i.e., a position was changed (flagged PEA) or a time/date field was changed (flagged TEA). If these fields can not be corrected with confidence then a reject flag (PER or TER respectively) is assigned to indicate that the field is in error. The "other/probe type" flag is assigned for errors that have resulted from operator errors.

1.1 Position Error (PE)

Description A position error is an error in a position field (latitude or longitude) which has been identified from the speed check program.

1.1A Accept Code: **PEA**

Use: The PEA flag is used if the position error can be successfully corrected with confidence in the new value.

Action: Manually correct the old value and re-run the speed check to validate the new value. Downgrade data to class 2 from the surface.

Quality Class: Class 2 from the surface.

1.1R Reject Code: **PER**

Use: The PER flag is used if the error can not be corrected.

Action: Do not correct the error when in doubt about the new value. Downgrade data to Class 3 from the surface and reject from the working archive.

Quality Class: Class 3 from surface.

1.2 Time Error (TE)

Description A time error is an error in the time/date field (hour, day, month, year) which has been identified from the speed check program.

1.2A Accept Code: **TEA**

Use: The TEA flag is used if the time error can be successfully corrected with confidence in the new value.

Action: Manually correct the old value and re-run the speed check to validate the new value. Downgrade data to class 2 from the surface.

Quality Class: Class 2 from the surface.

1.2R Reject Code: **TER**

Use: The TER flag is used if the error can not be corrected.

Action: Do not correct the error when in doubt about the new value. Downgrade data to Class 3 from the surface and reject from the working archive.

Quality Class: Class 3 from surface.

1.3 Other/Probe Type Error (OP)

Description An other/probe type error occurs when the probe type (or other value in header field) is entered incorrectly by the observer (e.g. T4 is entered instead of T7 for probe type).

1.3A Accept Code: **OPA**

Use: The OPA flag is used if the error can be successfully corrected with confidence in the new value or if the error had no effect on the quality of the data.

Action: Manually correct and replace the new value with the old value. Downgrade data to class 2 from the surface.

Quality Class: Class 2 from the surface.

1.3R Reject Code: **OPR**

Use: The OPR flag is used if the error can not be successfully rectified or there is an element of doubt about the new value to be substituted. The data is therefore considered to be uncorrectable.

Action: Downgrade data to Class 3 from the surface and reject from the working archive.

Quality Class: Class 3 from the surface.

1.4 Repeat Drop (RE)

Description A repeat drop is defined as an XBT deployed within 15 minutes of another one due to:

- Suspected previous probe malfunction,

- Desire to confirm a suspected real feature, or

- High density sampling

1.4A Accept Code: **REA**

Use: The REA flag is used if a repeat drop was done for one of the reasons outlined above.

Action: There is no change to the class of data.

Quality Class: Class 1 from the surface.

1.4R Reject Code: **RER**

Use: The RER flag is used if a repeat drop is considered dubious due to a malfunction.

Action: Downgrade data to Class 3 from the surface and reject from the working archive.

Quality Class: Class 3 from surface.

1.5 Duplicate Drop (DU)

Description A duplicate drop is one of two or more copies of an XBT profile that is already in the database. One copy will usually be accepted as superior and retained, though flagged with the DUA code. All others will be rejected with the code DUR.

1.5A Accept Code: **DUA**

Use: The DUA flag is used if a drop is a second copy of an XBT profile that is already in the database. It is usually superior (i.e., a full resolution version of a corresponding BATHY message).

Action: There is no change to the class of data.

Quality Class: Class 1 from the surface.

1.5R Reject Code: **DUR**

Use: The DUR flag is used if a drop is a second copy of an XBT profile that is already in the database. It is usually inferior (i.e., a BATHY message version of a corresponding full resolution drop).

Action: Downgrade data to Class 3 from the surface and reject from the working archive.

Quality Class: Class 3 from the surface.

2. Recorder Flags

The components of the XBT system include a recorder/processor that processes the data received over the fine wire link from the XBT via the launcher to the computer. This processor unit conditions, digitizes and transmits the data. Errors in the measurement of temperature by the probe can be caused by malfunctions in any of the components. The Recorder Flags have been defined to distinguish between these errors. The faults are often particular to a given brand of XBT system (Sippican, Bathy Systems or PROTECNO), or a particular hardware/software component of the system.

2.1 Surface Spikes (CS)

Description Surface spikes are caused by a minor start-up transient problem that leads to inaccurate temperature measurements in the top few metres of a temperature profile (For more information, refer to Roemmich and Cornuelle, 1987, and Bailey et al., 1989).

2.1A Accept Code: **CSA**

Use: The CSA flag is applied to all XBT profiles in which the surface spike is undetectable below 3.7 m depth, as the start-up transient problem is ubiquitous. In the rare case where the surface transient is detected below 3.7 m depth, but the overall quality of the data is considered to be unaffected, the affected values are replaced by 99.99.

Action: Surface data is removed to 3.7 m depth and replaced with 99.99 to indicate no data. No change to the class of data.

Quality Class Class 1 from the surface.

2.1R Reject Code: **CSR**

Use: The CSR flag is used if the surface transient is detectable below 3.7 m depth and the quality of the data is considered to be affected.

Action: Downgrade data to Class 3 from the surface and reject from the working archive.

Quality Class: Class 3 from the surface.

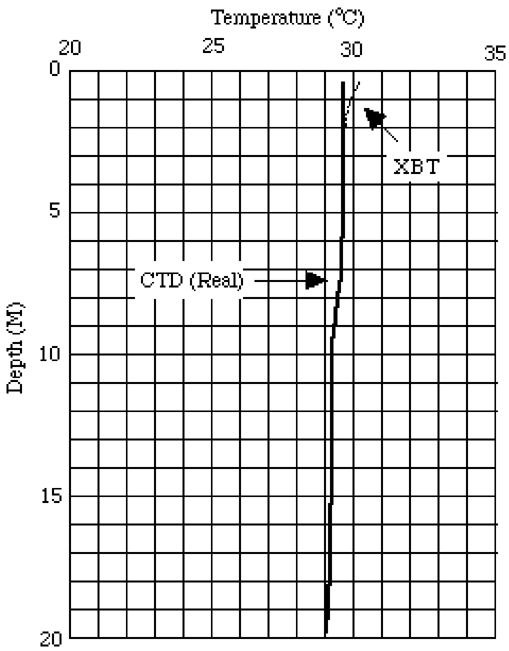


Figure 2.1 Surface Spike Start up Transient Problem (CS)

2.2 Test Probe (TP)

Description Test probes and devices are regularly used for testing or calibrating XBT systems. A test probe is recognized by a characteristic isothermal temperature profile, usually 1.5°C ±0.15°C.

2.2A Accept Code: N/A

2.2R Reject Code **TPR**

Use: The TPR flag is used in all cases where a test probe has been used.

Action: Downgrade test data to Class 4 from the surface and delete from the working archive on all occasions.

Quality Class: Class 4 from the surface.

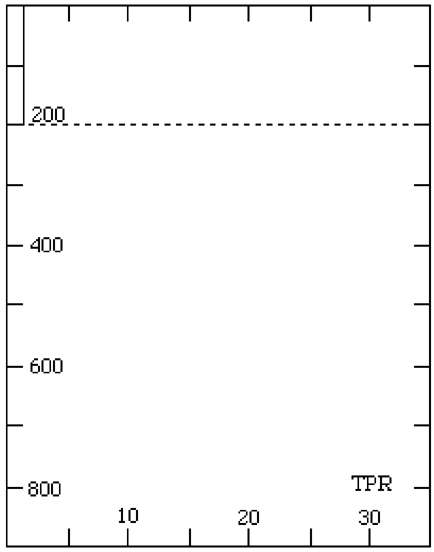


Figure 2.2R Test Probe (TPR)

2.3 Bathy Systems Software Error or Modulo 10 Spikes (MO)

Description The Bathy Systems Software Error is termed Modulo 10 Spikes because it is a data acquisition software problem associated with early versions of the Bathy Systems SA-810 XBT system in which a spike is introduced at 10 point intervals (i.e., every tenth digitization) in the profile data.

2.3A Accept Code: **MOA**

Use: The MOA flag is used if regular spiking is seen in a profile that has been recorded with a SA-810 XBT system.

Action: Spikes are replaced with linearly interpolated values. Downgrade data to class 2 from the surface.

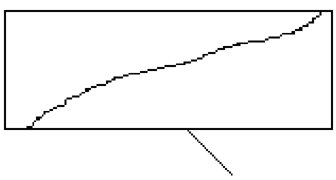
Quality Class: Class 2 from the surface.

2.3R Reject Code: **MOR**

Use: The MOR flag is used when large spikes (>0.2°C) which are difficult to interpolate are seen in a profile that has been recorded with a SA-810 XBT system.

Action: Downgrade data to Class 3 from the surface and reject from the working archive.

Quality Class: Class 3 from the surface.



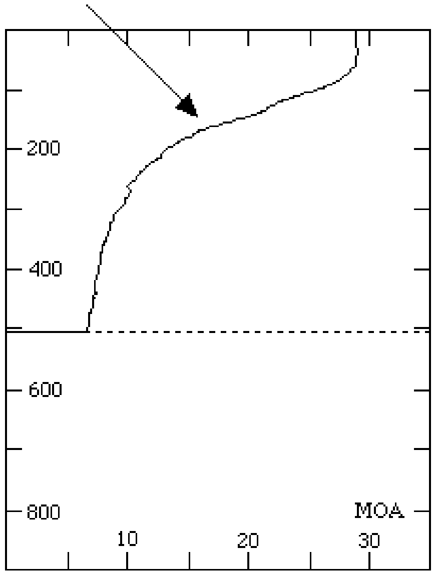


Figure 2.3A Modulo 10 Spikes Accept (MOA)

2.4 PROTECNO Systems Leakage or PET Fault (PF)

Description The PROTECNO Systems Leakage or PET fault is a problem specific to the PROTECNO recorder/processor that causes a leakage-type of malfunction. This can often be masked by the temperature gradient. Generally the leakage is more evident toward the bottom of a profile, where the temperature gradient is small. It is a common fault in data recorded by earlier versions of this System.

2.4A Accept Code: **PFA**

Use: The PFA flag is used when the beginning of the PET problem is not obvious (i.e., temperature at depth is consistent relative to neighbouring profiles) because it has been masked by the temperature gradient. The suspected start of a PET problem is flagged PFA as a cautionary measure.

Action: Check profile with a repeat or neighbouring profile. Downgrade the data to Class 2 from depth of anomaly.

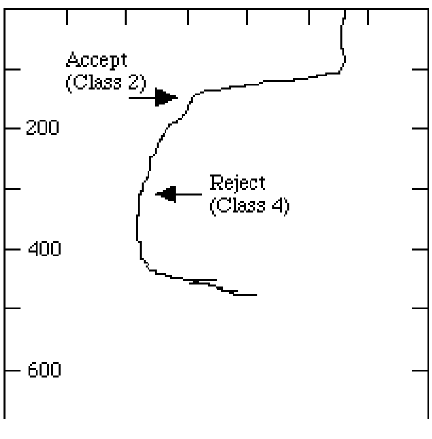
Quality Class: Class 2 from depth of suspected PET fault.

2.4R Reject Code: **PFR**

Use: The PFR flag is used if clear leakage occurs in a profile that has been recorded with a PROTECNO System, (i.e., the temperature at depth is inconsistent or warmer compared to neighbouring profiles).

Action: Downgrade data to Class 3 from depth of anomaly and reject from the working archive.

Quality Class: Class 3 from starting depth of PET fault.



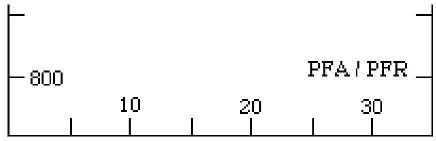


Figure 2.4 PET Fault Accept / Reject (PFA / PFR)

2.5 Bathy Systems Leakage or Cusping (CU)

Description Bathy Systems Leakage or cusping is a malfunction particular to early versions of the Bathy System SA-810 unit. Leakage associated with this recorder/processor causes a characteristic cusping signal to be embedded in the profile.

2.5A Accept Code: **CUA**

Use: The CUA flag is used if small amplitude (<0.2°C) periodic cusping is embedded in a profile recorded with an early Bathy Systems SA-810 unit and the error is considered small enough not to seriously effect the overall quality of the data.

Action: Downgrade data to Class 2 from depth of anomaly.

Quality Class: Class 2 from the start of cusping.

2.5R Reject Code: **CUR**

Use: The CUR flag is used if large amplitude (>0.2°C) periodic cusping is embedded in a profile recorded with a Bathy Systems SA-810 unit.

Action: Downgrade data to Class 3 from depth of anomaly and reject from the working archive.

Quality Class: Class 3 from start of cusping.

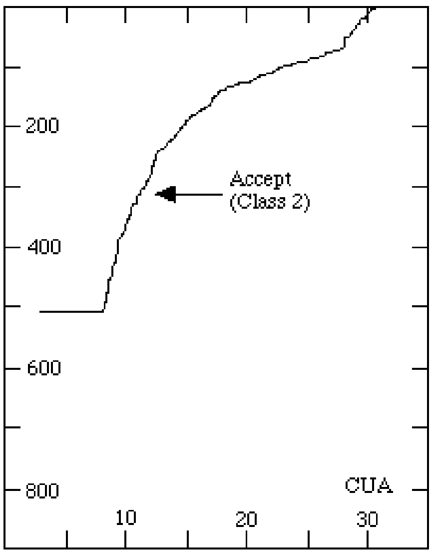


Figure 2.5A Cusping Error Accept (CUA)

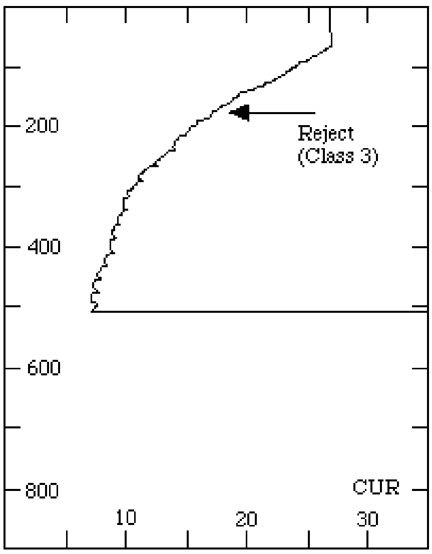


Figure 2.5R Cusping Error Reject (CUR)

2.6 Bathy Systems Bowing Problem or Bowed Mixed Layer (BO)

Description The Bathy Systems Bowing Problem or bowed mixed layer is an apparently inconsistent temperature measurement observed with an early version of the Bathy systems SA-810 XBT recorder (see Bailey et al., 1989). This problem manifests itself as an erroneous, gradual increase (bowing) in the temperature profile with depth that is most notable in the mixed layer zone (i.e., a normally isothermal layer of constant temperature). The apparent cause is insufficient current being driven down the XBT wire by the SA-810 recorder. The wire is only quality assured to carry around 150-200 microamps, and the early version of the SA-810 drives approximately 20 microamps down the wire. Any slight imperfections in the wire (such as damage to the insulation) cause problems at these lower current levels.

2.6A Accept Code: **BOA**

Use: The BOA flag is used if the magnitude of the resulting error is small (i.e., warming of ~0.2°C in the mixed layer) or difficult to detect. BOA can be used as a cautionary flag to mark a potentially realistic inversion detected in the mixed layer of a profile recorded with a Bathy Systems SA-810 unit.

Action: Downgrade data to Class 2 from the surface.

Quality Class: Class 2 from the surface.

2.6R Reject Code: **BOR**

Use: The BOR flag is used if an unrealistic inversion (warming of >0.2°C in a region where inversions have not previously been observed) is detected in the mixed layer of a profile recorded with a Bathy Systems SA-810 unit).

Action: Downgrade data to Class 3 from the surface and reject from the working archive.

Quality Class: Class 3 from surface.

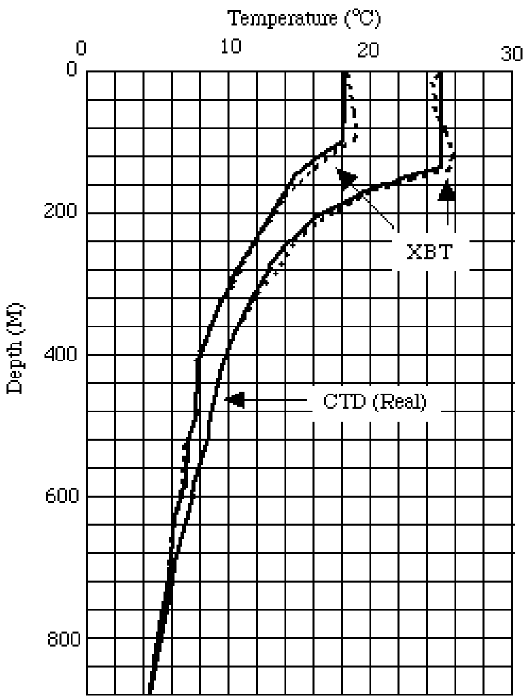


Figure 2.6 Bathy Systems Bowing Problem or Bowed Mixed Layer

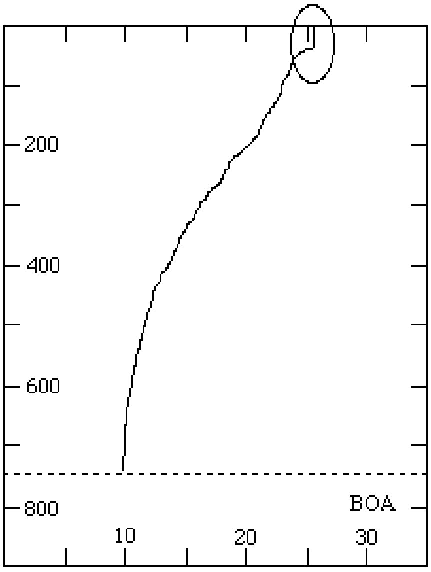


Figure 2.6A Bowed Mixed Layer Accept (BOA)

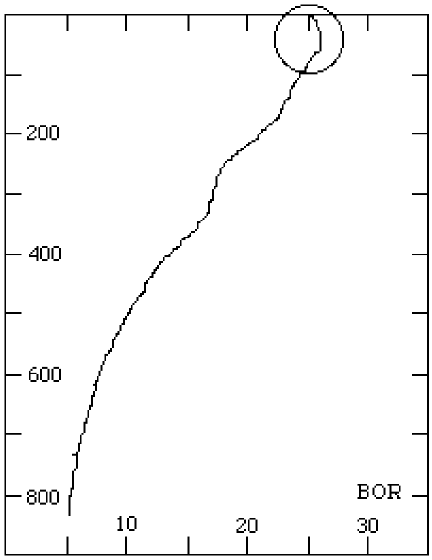


Figure 2.6R Bowed Mixed Layer Reject (BOR)

2.7 Sippican MK-9 Processor Malfunction or Sticking Bit Problem (SB)

Description The Sippican MK-9 Processor Malfunction or Sticking bit problem is a Sippican MK-9 firmware problem associated with the storage of bit information that results in continuous, small amplitude, step-like features in the profile. The steps can usually be filtered using a running mean or a median filter (on most occasions a median filter is used over 19 points), without degradation to the overall profile data.

2.7A Accept Code: **SBA**

Use: The SBA flag is used if small amplitude step-like features are observed in a profile recorded with a version of the MK-9 unit known to exhibit this problem.

Action: Apply a 19 point median filter with coefficients of 0.0526. Downgrade data to Class 2 from the surface.

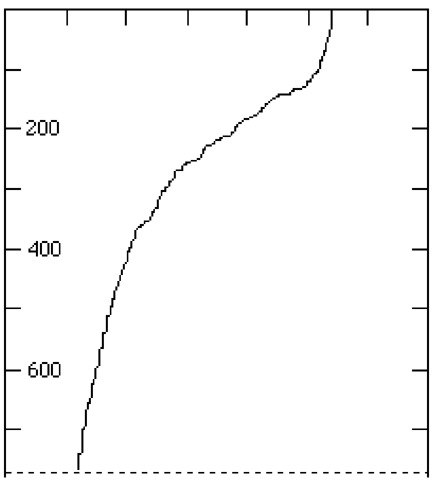
Quality Class: Class 2 from surface.

2.7R Reject Code: **SBR**

Use: The SBR flag is used if large amplitude step-like features are observed in a profile recorded with a version of the MK-9 unit known to exhibit this problem.

Action: Downgrade data to Class 3 from the surface and reject from the working archives.

Quality Class: Class 3 from surface.



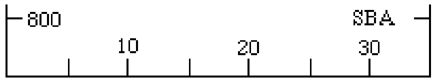


Figure 2.7A Sticking Bit Problem Accept (SBA)

2.8 Sippican MK-9 Timing Delay Problem or Driver Error (DR)

Description The Sippican MK-9 timing delay problem or driver error is an error in the recognition of the start of descent of an XBT (i.e., probe contact with water) that results in a depth error. This error has been detected during testing of some versions of the Sippican MK-9/MS-DOS XBT system. The problem is due to a software error in the recognition and handling of different versions of the GPIB (interface from MK-9 to XBT) driver routines. The resultant data errors are highly erratic and random in nature, and in most cases the degree of depth error is indeterminable in data collected in the field under normal conditions. Later versions of the software do not suffer from this problem. (For more information refer to Intergovernmental Oceanographic Commission, 1992: Summary report on the Ad Hoc Meeting of the IGOSS Task Team on Quality Control for Automated Systems, Marion, Massachusetts, USA, 36 June 1991. IOC/INF-888, pp 144).

2.8A Accept Code: **DRA**

Use: The DRA flag is used on all XBT profiles that were recorded with the offending software/hardware combination. The data was corrected by adding the number of metres corresponding to the MODE of the timing delay (2.6 s) as calculated by bench top tests of the relevant equipment. A further 4 metres of data has been deleted due to start up transients taking the total depth of affected data to 20 m.

Action: Downgrade data to Class 2 from the surface.

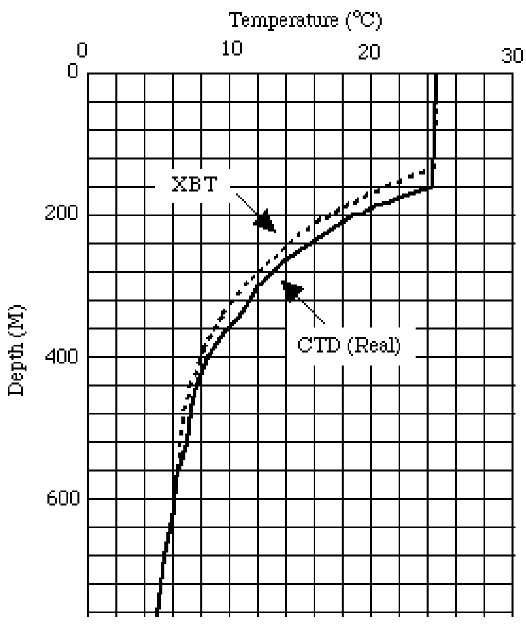
Quality Class: Class 2 from surface.

2.8R Reject Code: **DRR**

Use: The DRR flag is used if the data do exhibit extreme inconsistencies and were recorded with the offending software/hardware combinations. No correction is applied.

Action: Downgrade data to Class 3 from surface and reject from the working archives.

Quality Class: Class 3 from surface.



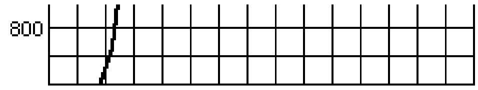


Figure 2.8 Timing Delay Problem or Driver Error (DR)

3. General Profile Flags

The "general profile" subcategory of flags includes malfunctions that are routinely observed and which require interpolation, deletion or filtering of the data. These include wire breaks and various types of spikes introduced by outside electrical interference. Many of the spike type errors can be interpolated or filtered with the remaining temperature records being unaffected. If the interference is severe this will not be the case, and the quality of the remainder of the temperature records in the profile will be downgraded. Also included in this category are cases where the probe hits the bottom and data below this depth must be rejected.

3.1 Hit Bottom (HB)

Description When the probe hits the bottom, the temperature trace usually goes isothermal (as the fall rate equation still assumes the probe to be descending). Contact with the bottom is often indicated by a small horizontal spike or undulation. The spike can be due to overheating of the thermistors or physical contact with the bottom. Data recorded beyond the hit bottom event is rejected as erroneous.

3.1A Accept Code: **HBA**

Use: The HBA flag is used if the isothermal layer recorded before a hit bottom event is suspected to be a real bottom isothermal boundary layer. This layer is often difficult to detect as the hit bottom spike may not always be clearly marked and the data recorded after the hit bottom event are also of constant temperature.

Action: Downgrade the data to Class 2 from depth of anomaly.

Quality Class: Class 2 from depth of possible isothermal boundary layer.

3.1R Reject Code: **HBR**

Use: The HBR flag is used if a hit bottom event is indicated by the trace.

Action: Downgrade data to Class 3 from depth of hit bottom indicator and delete from working archive.

Quality Class: Class 3 from depth of hit bottom event.

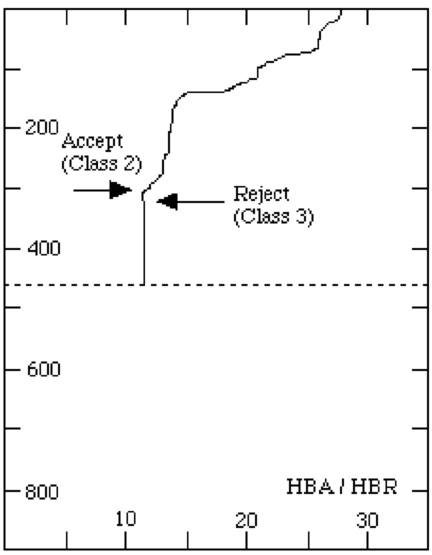


Figure 3.1 Hit Bottom Accept / Reject (HBA / HBR)

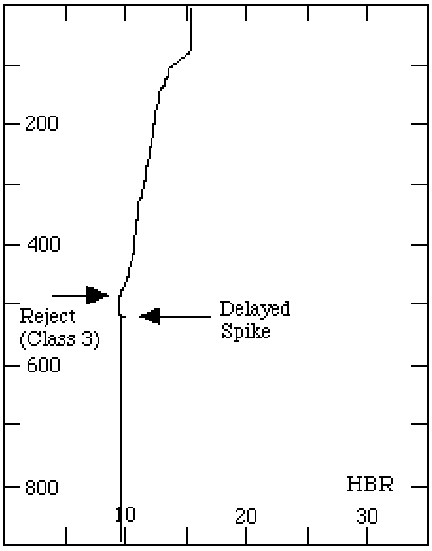


Figure 3.1R Hit Bottom Reject (HBR)

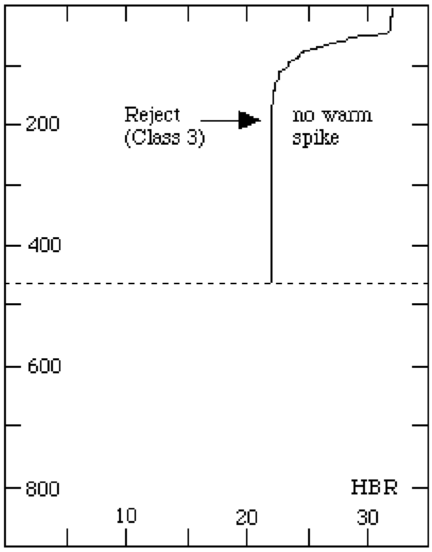


Figure 3.1R Hit Bottom Reject (HBR)

3.2 Wire Break (WB)

Description When the XBT wire breaks, a short circuit causes the temperature readings to go off scale either to the low (wire breaks from the spool in the launcher) or to the high (wire breaks from the descending probe's spool) temperature end of the scale. The main causes of wire breaks can be fouling or if the terminal depth of the probe is reached (i.e., a good XBT cast in deep water ends with a wire break). Often a wire stretch will precede a wire break (see also **WS** wire stretch).

3.2A Accept Code: N/A

3.2R Reject Code: **WBR**

Use: The WBR flag is used if the bottom of the XBT profile exhibits a sudden deflection to the high or low temperature end of the scale.

Action: Downgrade data to Class 4 from depth of initial point of damage and delete from working archive.

Quality Class: Class 4 from depth of wire break.

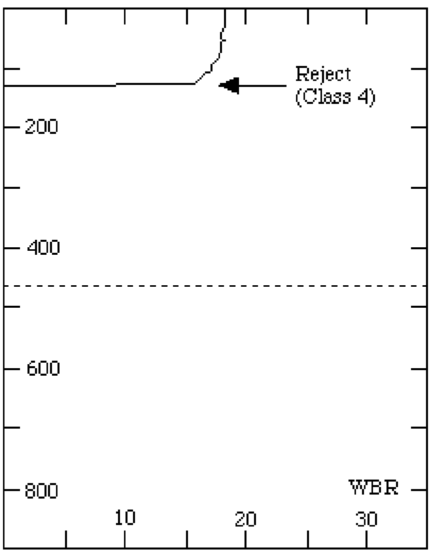


Figure 3.2R.1 Wire Break Reject
From Launcher Spool (WBR)

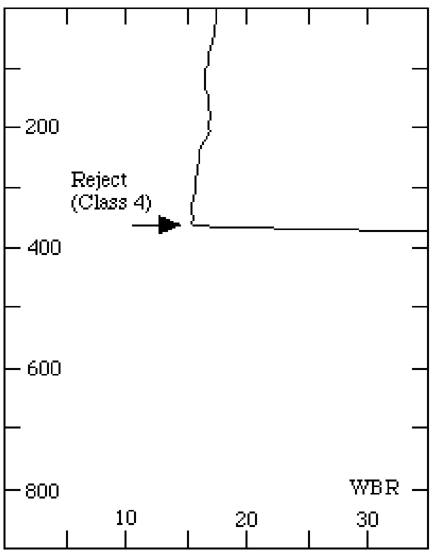


Figure 3.2R.2 Wire Break Reject
From Probe Spool (WBR)

3.3 Spikes (SP)

Description Isolated or intermittent spikes can be the result of external electrical or electromagnetic interference that influences the XBT system's output. Ship's radio signals, lightning and XBT wire shorting against the side of the ship can often cause spikes in the profile. Spikes may appear to be severe but temperatures may often be successfully interpolated. A spike in the profile data is generally considered to be >0.2°C as the accuracy of the XBT instrument is rated to ±0.15°C so that noise of this order or smaller can usually be ignored.

3.3A Accept Code: **SPA**

Use: The SPA flag is used if the spike is restricted to a narrow range of depths (i.e., only one or two temperature records) and the remaining temperature records are considered to be unaffected after interpolation.

Action: Remove and linearly interpolate data between erroneous points. Downgrade data to class 2 from depth of anomaly.

Quality Class: Class 2 from depth of spike.

3.3R Reject Code: **SPR**

Use: The SPR flag is used if severe spiking (>0.2°C and over a wide range of depths) occurs which can not be interpolated and the remaining temperature records are considered unreliable.

Action: Downgrade data to Class 4 from depth of anomaly and delete from working archive.

Quality Class: Class 4 from depth of spike.

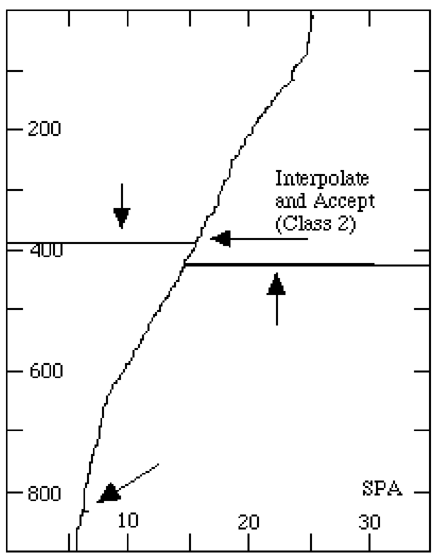


Figure 3.3A Spikes Accept (SPA)

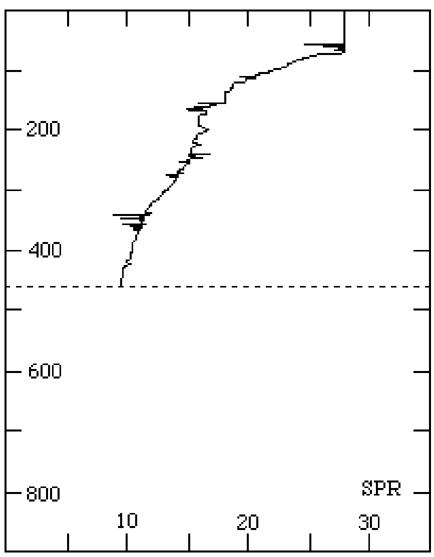


Figure 3.3R Spikes Reject (SPR)

3.4 High Frequency Interference (HF)

Description As for spikes, high frequency interference is caused by electrical, or electromagnetic, interference, but results in continual spiking over a wide range of depths. Interference may sometimes appear severe but the temperature records underneath can often be successfully interpolated by filtering.

3.4A Accept Code: **HFA**

Use: The HFA flag is used if the interference superimposed on a valid profile can be filtered without affecting the underlying profile. The validity of the underlying profile is established through comparison with neighbouring profiles.

Action: Apply a standard median filter or weighted mean filter to the selected number of data points. Re-check the profile to verify that spikes have been removed and compare to neighbouring profiles to ensure it has not been corrupted. Downgrade data to Class 2 from depth where filter was first applied.

Quality Class: Class 2 from depth of filtering.

3.4R Reject Code: **HFR**

Use: The HFR flag is used if there is severe interference or if filtering fails and the temperature records are considered to be corrupt.

Action: Downgrade data to Class 3 from start of anomaly and reject from working archive.

Quality Class: Class 3 from start depth of interference.

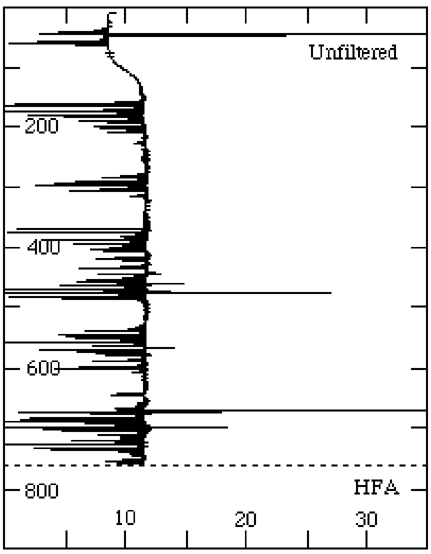


Figure 3.4A High Frequency Accept (HFA)

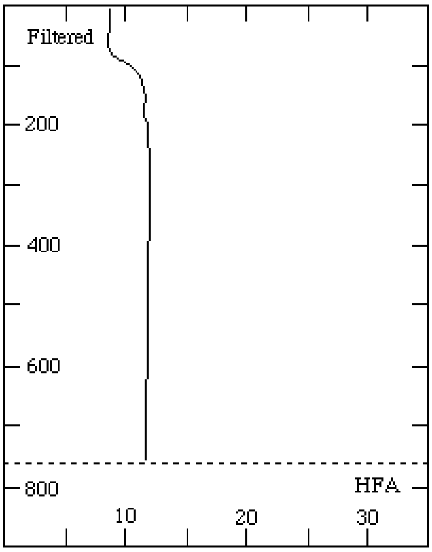


Figure 3.4A High Frequency Accept (HFA)

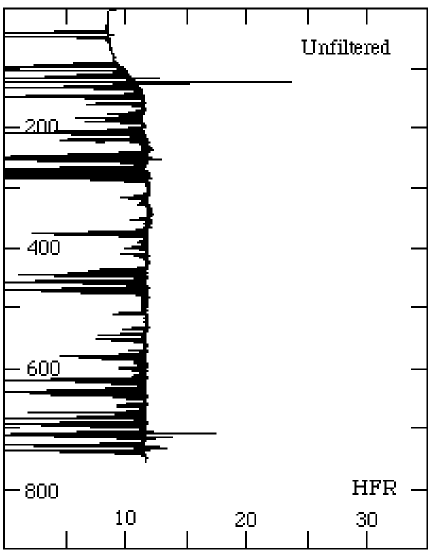


Figure 3.4R High Frequency Reject (HFR)

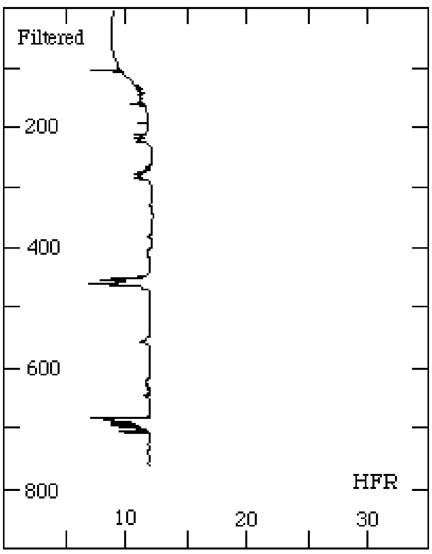


Figure 3.4R High Frequency Reject (HFR)

3.5 Insulation Penetration (IP)

Description An insulation penetration appears as a sharp spike(s) towards the high temperature end of the scale, generally followed by a gradual recovery. This is caused by damage to the wire insulation. The insulation damage will tend to heal itself by the interaction between the wire and seawater; however caution must be observed as the recovery may not be complete. Severe insulation penetration causes continual elevated temperatures from the depth of the leakage. (Note: insulation penetration is a special form of leakage, see also

LE leakage.)

3.5A Accept Code: **IPA**

Use: The IPA flag is used if the temperature is considered to have quickly and fully recovered from signs of insulation damage. There is a consistency of temperature readings at depth when compared with neighbouring profiles.

Action: Replace the spike with linearly interpolated data. Downgrade data to Class 2 from point of anomaly.

Quality Class: Class 2 from depth of spike.

3.5R Reject Code: **IPR**

Use: The IPR flag is used if the profile is deemed not to have fully recovered from the insulation penetration spike. There is an inconsistency of temperature readings at depth when compared with neighbouring profiles.

Action: Downgrade data to Class 3 from depth of anomaly and reject from working archive.

Quality Class: Class 3 data from depth of spike.

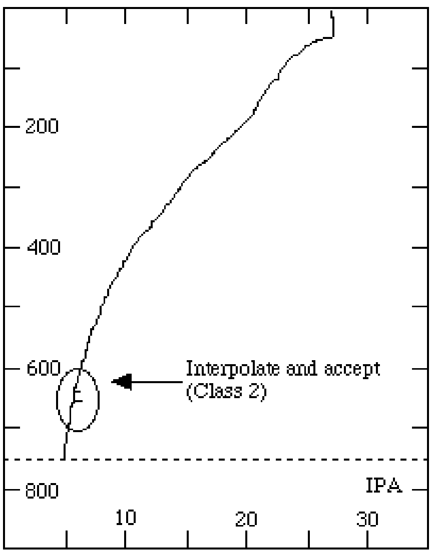


Figure 3.5A Insulation Penetration Accept (IPA)

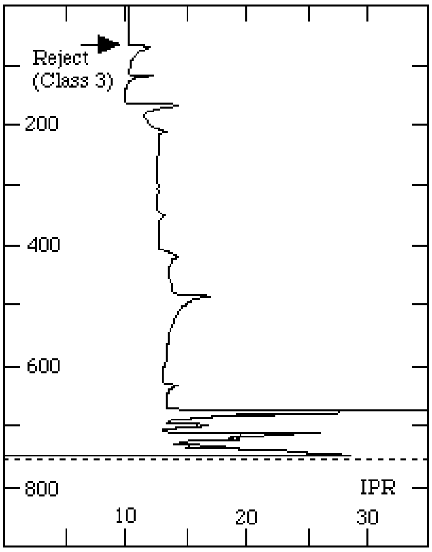


Figure 3.5R Insulation Penetration Reject (IPR)

3.6 Constant Temperature Profile (CT)

Description A constant temperature profile is a record of temperature data that appears abnormally isothermal. This event is the outcome of a faulty probe (broken thermistor or the weighted nose has broken off the probe) resulting in the system's inability to detect a change in resistance and hence temperature.

3.6A Accept Code: **CTA**

Use: The CTA flag is used if the sea surface temperature of an isothermal profile is considered consistent (valid) on cross checking with neighbouring profiles.

Action: Keep profile data to 10 metres depth then flag CTR to downgrade data to Class 3 below 10 metres and reject from working archive.

Quality Class: Class 1 to 10 metres; Class 3 below.

3.6R Reject Code: **CTR**

Use: The CTR flag is used to reject data from the surface if the profile is isothermal and if the surface temperature is inconsistent (invalid) with that of neighbouring profiles. It is also used to reject data below 10 m depth in profiles flagged CTA, and to reject data from the depth where temperatures become anomalously constant when no other fault is evident.

Action: Downgrade data to Class 3 from the affected depth and reject from working archive.

Quality Class: Class 3 from the depth of the fault.

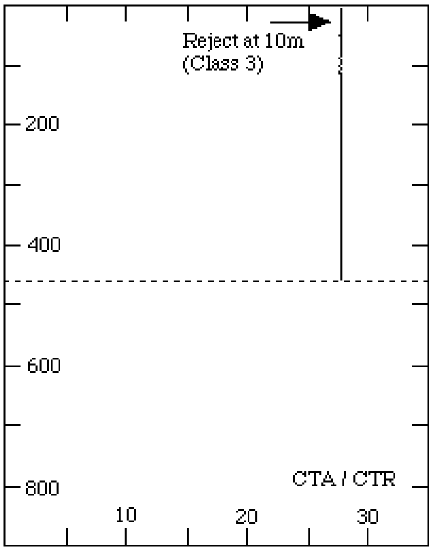


Figure 3.6 Constant Temperature Profile Accept / Reject (CTA / CTR)

3.7 No Trace (NT)

Description No trace indicates that there is no profile data recorded or that the data is completely off-scale. This can be due to a number of reasons such as a wire break before the probe makes contact with the water or an observer launching a probe before the system's set-up procedures are complete.

3.7A Accept Code: N/A

3.7R Reject Code: **NTR**

Use: The NTR flag is used if no data has been recorded or if recorded data is totally off scale.

Action: Downgrade data to Class 4 from the surface and delete from working archive.

Quality Class: Class 4 from the surface.

3.8 No Good (NG)

Description A "no good" profile is a profile in which the data are completely and obviously erroneous. This can happen for any of the reasons described. This flag is also used to "clean up" (delete) data that would otherwise be retained as Class 3 but is obviously Class 4.

3.8A Accept Code: N/A

3.8R Reject Code: **NGR**

Use: The NGR flag is used if all or a portion of the profile is obviously erroneous.

Action: Downgrade data to Class 4 from depth of the error and delete from working archive.

Quality Class: Class 4 from depth of the error.

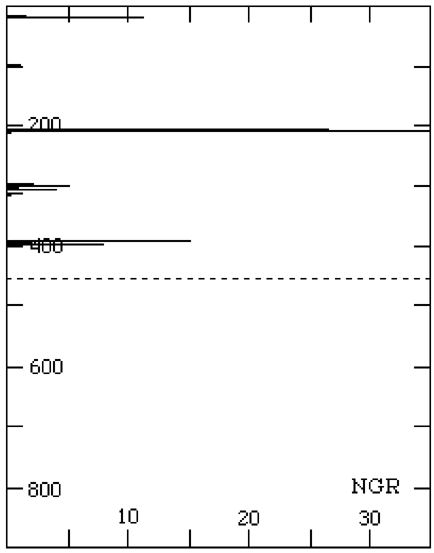


Figure 3.8 No Good Reject (NGR)

4. Inversion / Wire Stretch Flags

Temperature inversions are common, real features of the ocean. An inversion is a stable increase of temperature with depth as a result of compensating salinity structure and is identified by a characteristic bulge to the high temperature side of an XBT profile. There is, however, a class of malfunctions (wire stretch) which can look very similar. Distinguishing between the two can be difficult. Whereas an inversion is a real increase of temperature with depth, a wire stretch because of an increase in tension in the wire (due to poor unreeling) can result in a similar bulge to the high temperature side of an XBT profile. The approach taken in the quality control of profiles showing an increase in temperature with depth, therefore, is to be conservative. Only those features that have either been confirmed by a check between neighbouring profiles (usually repeat drops), or have been observed in an area where inversions are known to occur are flagged as real. Unconfirmed features are flagged according to the degree of confidence we have in them. If the anomaly is suspected to be erroneous it should be flagged as a wire stretch.

4.1 Inversion Confirmed Flag (IVA)

Description An inversion is defined as a confirmed increase in temperature with depth observed at some point in the profile. Confirmation is established through the observation of the same feature in a neighbouring (usually a repeat) drop. These features usually occur in specific regions.

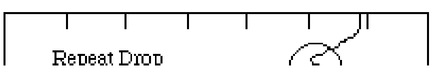
4.1A Accept Code: **IVA**

Use: The IVA flag is used if the inversion is confirmed to be a real feature by observing the same feature in a repeat or neighbouring drop.

Action: Verify if inversions have previously been observed in the region or are found in neighbouring drops. No change to class of data.

Quality Class: Class 1 from the surface.

4.1R Reject Code N/A



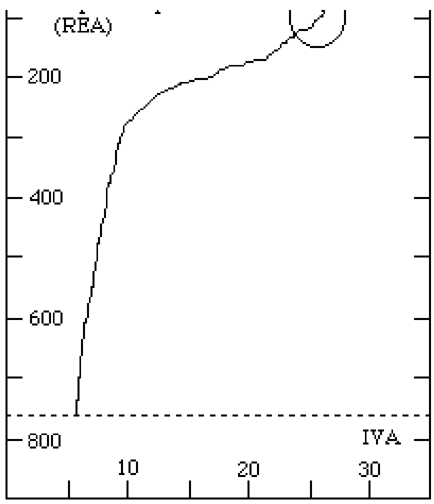


Figure 4.1 Inversion Confirmed (IVA)

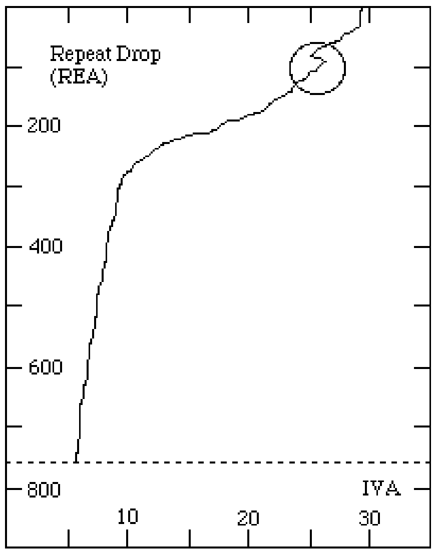


Figure 4.1 Inversion Confirmed (IVA)

4.2 Inversion in Mixed Layer Confirmed "Nub" Flag (NUA)

Description A nub is a special type of inversion in which an increase of temperature with depth is observed within or at the base of the mixed layer. Confirmation is established through the observation of the same feature in a neighbouring (usually a repeat) drop.

4.2A Accept Code: **NUA**

Use: The NUA flag is used if the nub is confirmed to be real by observation of the same feature in the mixed layer of a repeat or neighbouring drop.

Action: Verify if nubs have previously been observed in the region or are found in neighbouring drops. No change to class of data.

Quality Class: Class 1 from the surface.

4.2R Reject Code N/A

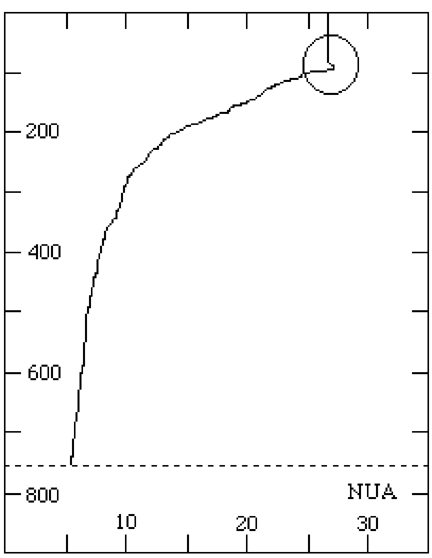


Figure 4.2.1 Inversion in Mixed Layer Confirmed "Nub" (NUA)

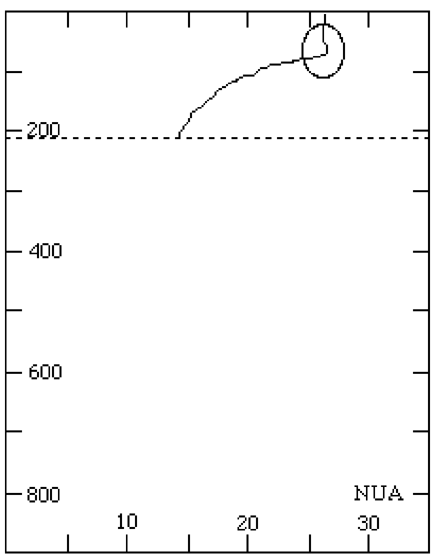


Figure 4.2.2 Inversion in Mixed Layer Confirmed "Nub" (NUA)

4.3 Inversion Probable Flag (PI)

Description A probable inversion is defined as an increase in temperature with depth observed at some point in the profile, but which is not fully confirmed by a repeat or neighbouring drop. The feature is considered to be probably real as inversions are known to occur in the region or similar features are found in neighbouring drops.

4.3A Accept Code **PIA**

Use: The PIA flag is used if an inversion can not be completely confirmed by a neighbouring profile but the feature is probably real, because similar features have previously been observed in the region and in neighbouring profiles.

Action: Check if similar anomalies occur in neighbouring drops or if inversions have previously been observed in the region. Downgrade data to Class 2 from depth of anomaly.

Quality Class: Class 2 from depth of probable inversion.

4.3R Reject Code N/A

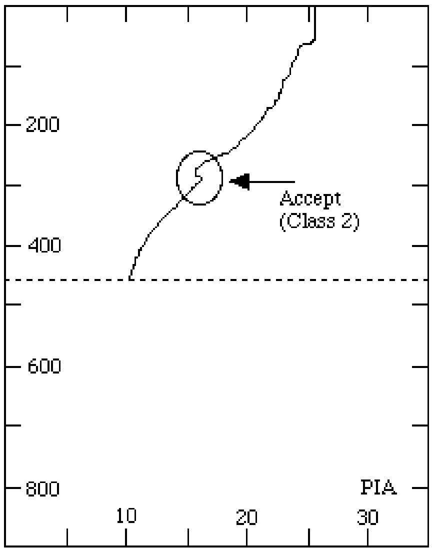


Figure 4.3 Probable Inversion (PIA)

4.4 Possible Wire Stretch Accept Flag (WSA)

Description A possible wire stretch is an apparent warming of temperature with depth at some point in the profile (usually small, ~0.2°C) which is considered to be unusual as there is little knowledge of inversions in the region and there is no confirmation from a neighbouring profile. The anomaly is accepted, however, because the magnitude of the inversion is small and/or there is also not enough evidence to completely doubt the profile.

4.4A Accept Code **WSA**

Use: The WSA flag is used if the magnitude of the anomaly (warming) is small enough (~0.2°C over a small range of depths) that it does not seriously effect the overall quality of the data.

Action: Check if similar anomalies are observed in neighbouring drops or have previously been observed in the region. Downgrade data to Class 2 from depth of anomaly.

Quality Class: Class 2 from depth of possible wire stretch.

4.4R Reject Code (See **WSR**, pg 62)

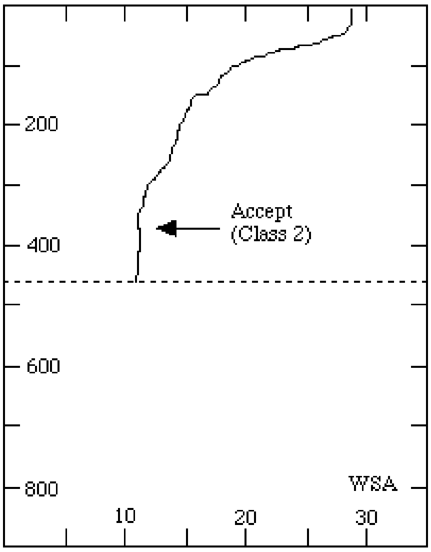


Figure 4.4.1 Wire Stretch Accept (WSA)

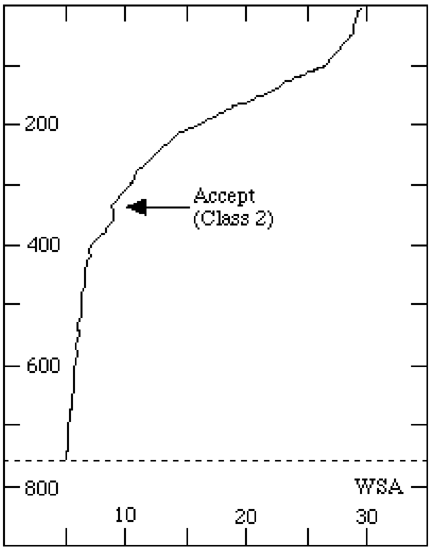


Figure 4.4.2 Wire Stretch Accept (WSA)

4.5 Wire Stretch Reject Flag (WSR)

Description A true wire stretch causes an abnormal increase of temperature with depth (usually > 0.2°C observed over a large range of depths). The feature is considered to be erroneous because temperatures at depth are inconsistent (warmer) when checked against neighbouring profiles. A wire stretch is often observed at the base of a trace before a wire break, (see also **WB** Wire Break), or if fouling or restricted unreeling occurs.

4.5A Accept Code (see **WSA**, pg 60)

4.5R Reject Code **WSR**

Use: The WSR flag is used if an unrealistic bulge to the high temperature end of the scale is present that does not fully recover.

Action: Downgrade data to Class 3 from depth of anomaly and reject from working archive.

Quality Class: Class 3 below depth of wire stretch.

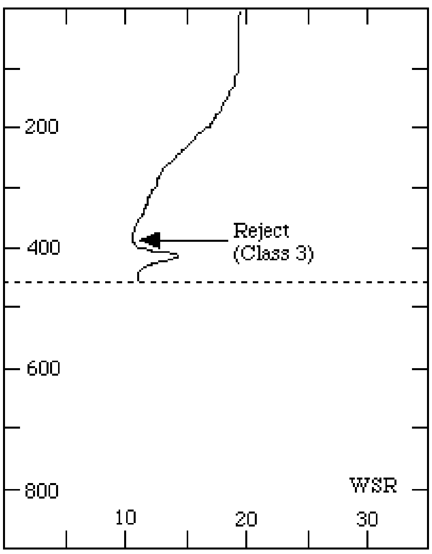


Figure 4.5.1 Wire Stretch Reject (WSR)

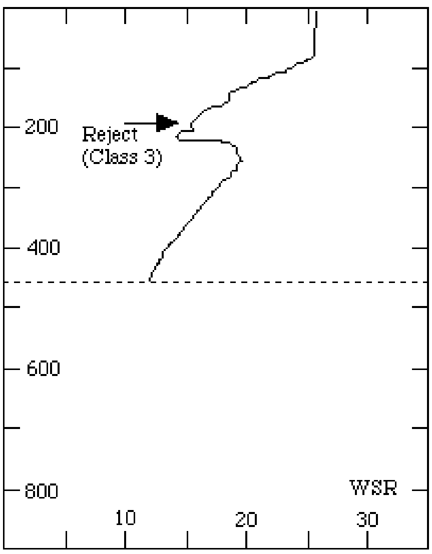


Figure 4.5.2 Wire Stretch Reject (WSR)

5. Structure / Signal Leakage Flags

Temperature profiles in the upper layers of the ocean can exhibit many types of real, fine scale structure that are generated by a variety of small scale mixing and turbulent processes. Fine structure specifically refers to structure in the hydrographic and flow fields of the ocean, on vertical scales of 1-100 metres. These are usually associated with horizontal scales of 1 m to 10 km and time scales of one minute to several days (McPhaden, 1985). One type of malfunction (leakage) can also result in temperature profiles with characteristics similar to fine scale structure. As was the case for inversions, it is often difficult to distinguish between the real feature and the malfunction so verification with neighbouring (or repeat) profiles and previous knowledge of the region is used for confirmation. Fine scale structure resulting from small scale mixing processes is commonly observed in a profile as many small step-like features or interleavings. Leakage may show similar characteristics; however the small-scale structure is often sharper and the temperatures below the depth of the anomaly will tend to be warmer when compared with neighbouring profiles. Like the inversion/wire stretch category there is again no clear black and white line between accepting or rejecting the profiles, and the different codes are allocated according to the degree of confidence that can be placed in the confirmation process. If the anomaly is suspected to be the result of a malfunction it should be flagged as leakage and rejected.

5.1a Fine Structure (Step-Like) Confirmed Flag (STA)

Description Fine Structure consists of step-like features or small interleaving observed in a profile over a range of depths, (usually 10-100 m) or the entire profile. Thermostads, well-mixed regions where temperature and density vary little with depth, also appear as step-like features and so are included in this category. Confirmation is established by observation of the same structure in a repeat or neighbouring drop. This feature can occur in many regions.

5.1aA Accept Code **STA**

Use: The STA flag is used if highly structured step-like features are confirmed in a neighbouring (usually repeat) drop.

Action: Verify if small scale features have previously been observed in the region or found in neighbouring (usually repeat) drops. No change to class of data.

Quality Class: Class 1 from the surface.

5.1aR Reject Code N/A

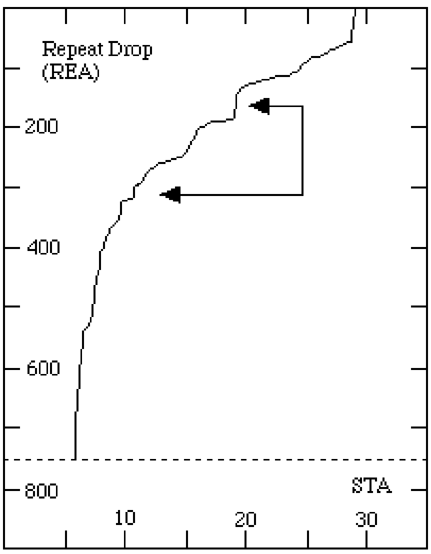


Figure 5.1a Fine Structure (Step-like) Confirmed (STA)

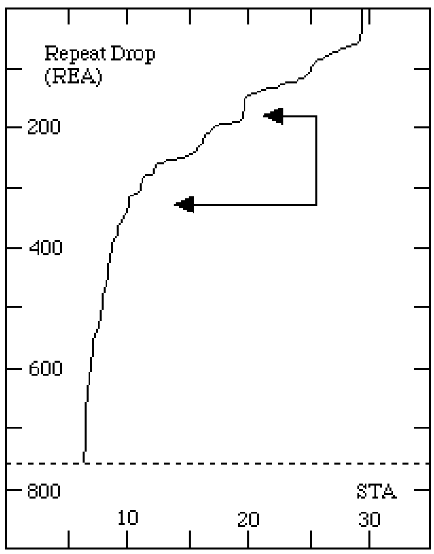


Figure 5.1a Fine Structure (Step-like) Confirmed (STA)

5.1b Fine Structure (Step-Like) Probable Flag (PS)

Description Probable fine Structure (step-like) appears as unconfirmed isothermal or step-like features (including thermostads) observed in a profile over a range of depths (usually 10-100 m) or the entire profile. The vertical gradient of the feature or features is substantially different from the background gradient and therefore resembles a cascade or staircase (see **FSA** for a description of another type of unconfirmed fine structure).

5.1bA Accept Code **PSA**

Use: The PSA flag is used if structured step-like features are observed in a drop but cannot be completely confirmed by a neighbouring profile. However, the feature is probably real because similar features have previously been observed in the region.

Action: Check if fine structure occurs in a neighbouring profile or has previously been observed in the region. Downgrade data to Class 2 from the surface.

Quality Class: Class 2 from the surface.

5.1bR Reject Code N/A

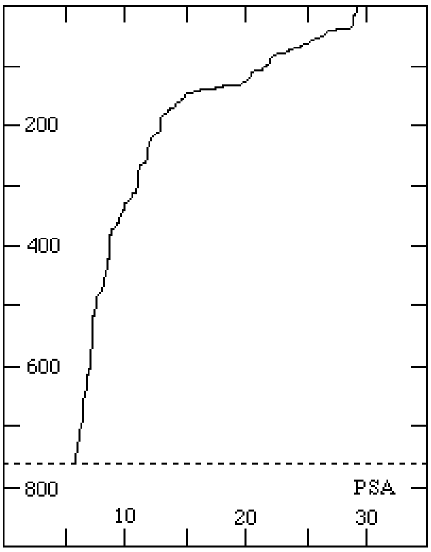


Figure 5.1b Fine Structure (Step-like) Probable (PSA)

5.2 Surface Anomaly, Fine Structure Special Case Flag (SA)

Description The surface anomaly is a special case of fine structure that is limited to the top 20 metres of the water column. A warm surface layer can sometimes form from solar heating and light winds (often referred to as the afternoon effect). The afternoon effect can warm surface layers of between 2-10 m thick by up to 1°C. Cooler freshwater layers due to precipitation or river-outflow can also cause a surface anomaly to develop. A surface anomaly is generally larger than 0.2°C. These surface features are often transient and can have small spatial scales so you must be cautious and remember that the XBT can have problems near the surface (see Surface Spikes **CS**, Bowing **BO**, and Insulation Penetration **IP**).

5.2A Accept Code **SAA**

Use: The SAA flag is used if a warm or cool anomaly (of >0.2°C) is detected in the top 20 metres of the water column.

Action: Check if surface anomalies have previously been observed in the region or found in neighbouring drops. Downgrade data to Class 2 from the surface.

Quality Class: Class 2 from the surface.

5.2R Reject Code N/A

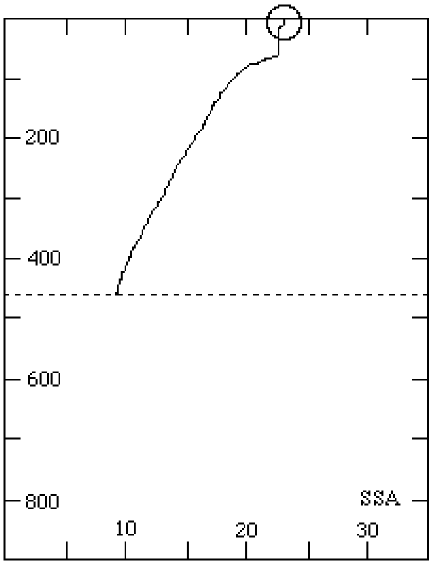


Figure 5.2 Surface Anomaly, Fine Structure Special Case (SSA)

5.3 Fine Structure Probable Flag (FS)

Description Probable fine structure appears as unconfirmed, small-scale structure superimposed on the temperature profile over a range of depths (usually 10-100 m) or in the entire profile. It often appears as small scale interleavings in the temperature profile. The structure is probably real because, although confirmation can not be established, fine structure has been known to occur in the region or similar features are observed in neighbouring drops.

5.3A Accept Code **FSA**

Use: The FSA flag is used if the fine-scale structure can not be completely confirmed by a neighbouring profile but validity is considered highly probable as similar features have previously been observed in the region.

Action: Check if fine structure occurs in a neighbouring profile or has previously been observed in the region. Downgrade data to Class 2 from the surface.

Quality Class: Class 2 from the surface.

5.3R Reject Code N/A

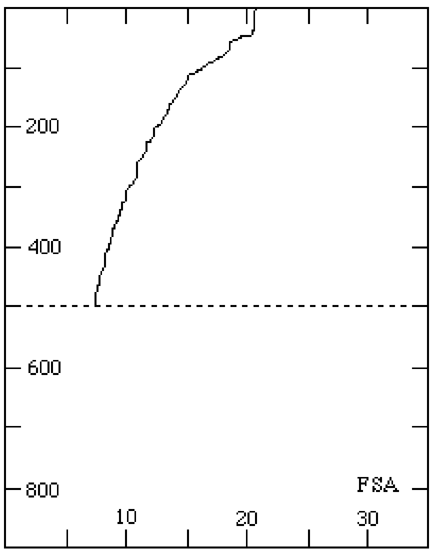


Figure 5.3 Fine Structure Probable (FSA)

5.4 Leakage Accept Flag (LE)

Description Leakage appears as apparent structure of "jitter" over a range of depths (or the entire profile) that is considered to be unusual as there is little evidence of similar structure in the region, and/or there is no confirmation from a neighbouring profile. This flag can be used if there is some element of doubt whether the XBT system is working correctly, i.e., if there is a suspected signal leakage problem with the recording equipment. Where structure is observed in a BATHY message LEA will often be used instead of FSA due to the low resolution of the data. Leakage can also be a result of insulation penetration (see **IPR**) which has not healed leading to continuous leakage, or damage to the launcher cable or recorder.

5.4A Accept Code **LEA**

Use: The LEA flag is used if the shape of the feature is somewhat characteristic of signal leakage ("jittery"), but the magnitude of the anomaly is small enough (~0.2°C over a range of depths) to be considered not to seriously effect the overall quality of the data and/or there is not enough evidence to completely doubt the profile.

Action: Check if similar anomalies are observed in neighbouring drops or have previously been observed in the region. Downgrade data to Class 2 from the surface.

Quality Class: Class 2 from the surface.

5.4R Reject Code **LER**

Use: If leakage is observed as erratic, sharp and unrealistic structure over a range of depths or the entire profile, the data must be rejected. Temperatures at depth are generally warmer than neighbouring profiles.

Action: Check profile with neighbouring drops and downgrade data to Class 3 from the depth of anomaly and reject from the working archive.

Quality Class: Class 3 from depth of leakage.

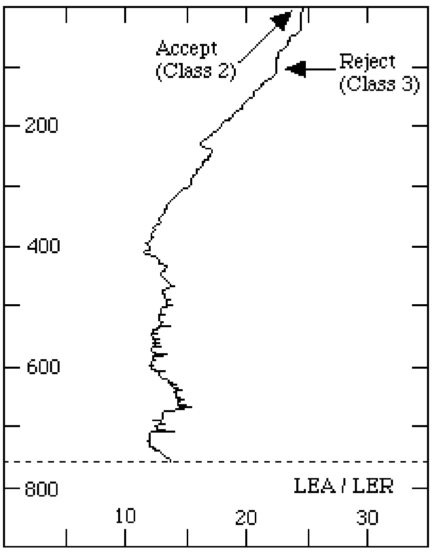


Figure 5.4A Leakeage Accept / Reject (LEA / LER)

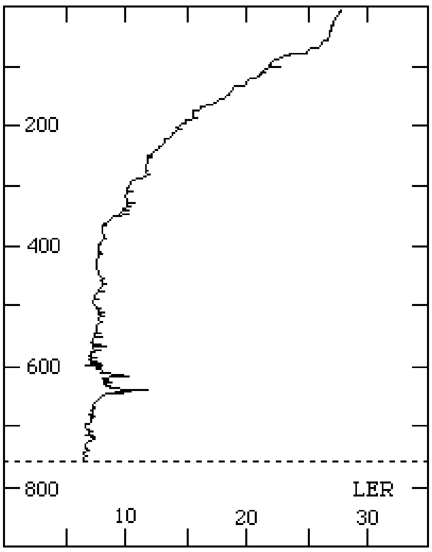


Figure 5.4R Leakage Reject (LER)

6. Eddy, Front or Current/ Temperature Offset Flags

Eddies, oceanic fronts and currents are common meso-scale features in the oceans. These often appear in profile data as distinct increases and/or decreases in the temperature over large depth ranges when compared to neighbouring profiles. Depending on the horizontal sampling interval, a series of temperature displacements with depth can sometimes be seen in alternating or sequential drops as the ship crosses an eddy, current system or frontal region. Again there are malfunctions which can resemble these real features. An indication that the XBT may have malfunctioned due to wire stretch (see WSA), leakage (see LER) or a probe defect (see TOR) is often an observed temperature difference (>0.2°C) at the bottom of the temperature profile when compared with its neighbours. Care must be taken to distinguish between such temperature offsets due to instrument malfunctions and ones due to real meso-scale features in the ocean. This is particularly true if the XBT does not sample to the bottom of the thermocline or if sampling is not at intervals that will resolve the horizontal space scales of the eddies, currents or fronts. Like the inversion/wire stretch and fine-structure/leakage categories there is again no clear black and white line between accept and reject flags and the different codes are allocated according to the degree of confidence that can be placed in the confirmation process. If the anomaly is considered to be the result of a malfunction, it should be flagged as such and rejected.

6.1 Eddy / Front / Current Confirmed Flag (EFA)

Description An eddy, front or current appears as an increase/decrease in temperature over large depth ranges when compared to a neighbouring profile. A temperature displacement can sometimes be seen in alternating or sequential drops as the ship track crosses a current, eddy system or frontal region. Confirmation of the feature is established if neighbouring (usually repeat) profile pairs each side of the front show similar temperatures at depth. Temperature sections along the ship track can be used as further evidence these features are real.

6.1A Accept Code **EFA**

Use: The EFA flag is used if neighbouring (usually repeat) profile pairs each side of the front show similar temperatures at depth.

Action: Verify eddy/front/current by repeat or neighbouring drops and establish if eddies/fronts/currents have previously been observed in the region. Plot the temperature section along the cruise track for further confirmation. No change to class of data.

Quality Class: Class 1 from the surface.

6.1R Reject Code N/A

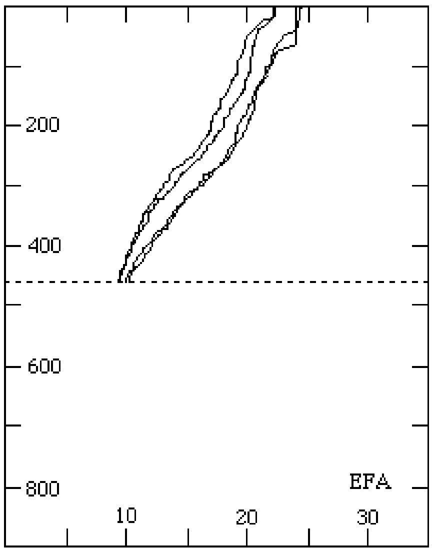


Figure 6.1 Eddy / Front Confirmed (EFA)

6.2 Temperature Difference at Depth Flag (TDA)

Description A difference in temperature at depth is observed when compared to neighbouring profiles. The temperature difference can occur over the entire profile but the defining feature is the offset at the bottom of the profile. The feature is probably real as eddies, fronts or currents are known to occur in the region, although there is no exact confirmation from neighbouring profiles.

6.2A Accept Code **TDA**

Use: The TDA flag is used if a temperature difference (>0.2°C) at depth is observed when compared to neighbouring profiles but this difference cannot be confirmed as real. Eddies or fronts are known to occur in the region, however, so the feature is considered to be probably real.

Action: Check if a similar anomaly has been observed in a neighbouring drop or previously in the region. Downgrade data to Class 2 from the depth of the divergence.

Quality Class: Class 2 from the depth of the divergence.

6.2R Reject Code N/A

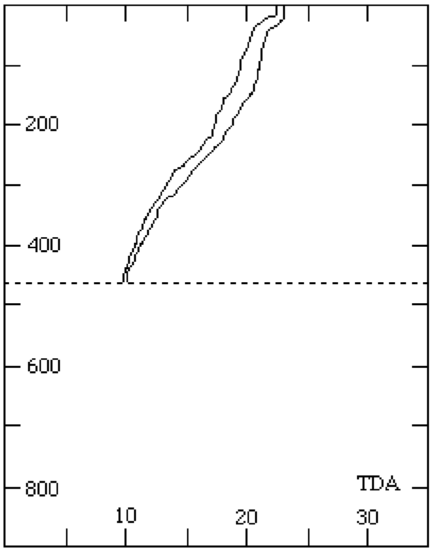


Figure 6.2 Temperature Difference at Depth (TDA)

6.3 Temperature Offset Reject Flag (TOR)

Description A temperature offset is an unrealistic temperature displacement observed over a large range of depths, which is not observed in neighbouring drops and has not previously been observed in the region.

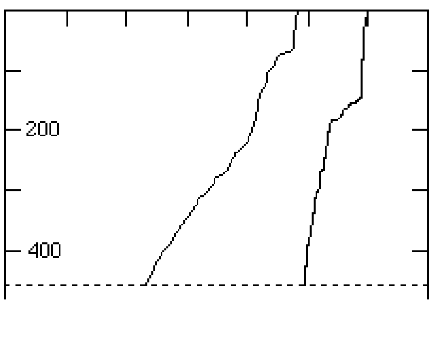
6.3A Accept Code N/A

6.3R Reject Code **TOR**

Use: The TOR flag is used if an unrealistic temperature difference can not be confirmed by a neighbouring drop and there is limited evidence that eddies or fronts occur in the region.

Action: Determine if temperature differences have previously been observed in the region. Downgrade data and reject from the working archive from the depth of the offset.

Quality Class: Class 3 from the depth of the offset.



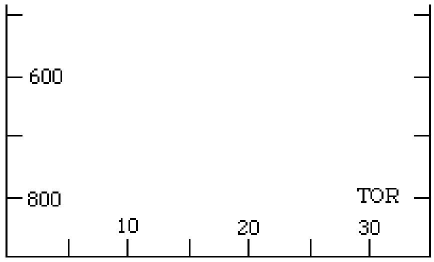


Figure 6.3 Temperature Offset Reject (TOR)

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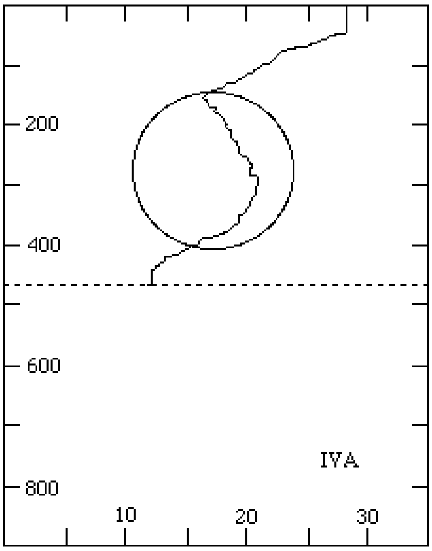
Acknowledgments

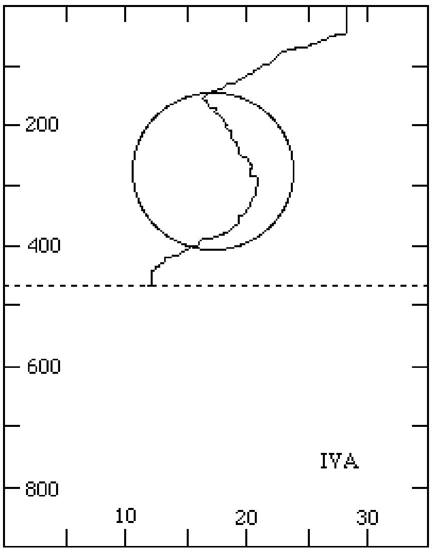
This 'cookbook' was completed with the generous help of Edwina Tanner from the Australian Oceanographic Data Centre (AODC) and Cher Page of the CSIRO Division of Oceanography.

And now just to make sure you know it all:

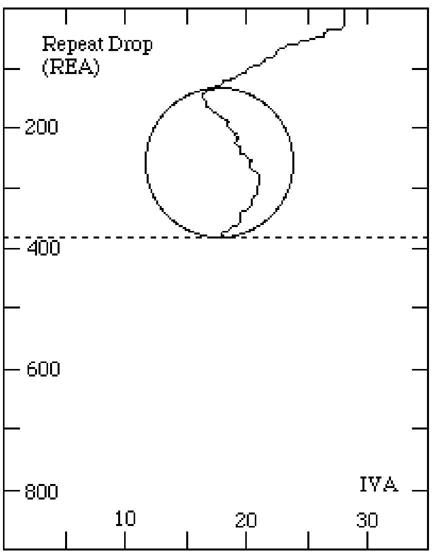


Would you accept or reject the above?
Now Turn the page:

And now just to make sure you know it all:



Would you accept or reject the above?
Now Turn the page:



This is confirmation in a repeat drop of the one above.
The inversion is a real depiction of Gulf outflow from the Arabian Sea.

Appendix A. Table of integer codes used to identify the Quality Control Flags

Category	Accept Feature		Reject Feature	
	Character Code	Integer Code	Character Code	Integer Code
Surface Spikes	CSA	1		
Modulo 10 Spikes	MOA	2	MOR	-2
Wire Break			WBR	-3
Hit Bottom	HBA	4	HBR	-4
PROTECHNO Leakage	PFA	5	PFR	-5
Inversion	IVA	6		
Nub	NUA	7		
Fine Structure	STA	8		
Wire Stretch	WSA	9	WSR	-9
Leakage	LEA	10	LER	-10
Bathy System Leakage (cusping)	CUA	11	CUR	-11
High Frequency Noise	HFA	12	HFR	-12
Insulation Penetration	IPA	13	IPR	-13
Spikes	SPA	14	SPR	-14
Bathy Systems Bowing	BOA	15	BOR	-15
Surface Anomaly	SAA	16		
Temperature Difference at Depth	TDA	17		
Temperature Offset			TOR	-17
Constant Temperature	CTA	18	CTR	-18
No Trace			NTR	-19
No Good			NGR	-20
Test Probe			TPR	-21
Repeat Drop	REA	24	RER	-24
Sippican MK-9 processor error (sticking bit)	SBA	27	SBR	-27
Other / Probe Error	OPA	28	OPR	-28
Fine Structure	PSA	29		
Sippican MK-9 Timing Delay	DRA	30	DRR	-30
Probable Inversion	PIA	31		
Eddy / Front	EFA	32		
Position error	PEA	33	PER	-33
Time / Date Error	TEA	34	TER	-34
Duplicate Drop	DUA	35	DUR	-35
Quality Control	QCA	36		
Probable Step-like Fine Structure	PSA	37		