
FAILURES AND MISCONCEPTIONS

FAILURES AND MISCONCEPTIONS

- **AIM OF THE TALK**
  - **-DESCRIBE FAILURES**
  - **-SHOW THEIR ORIGIN (MISCONCEPTIONS)**
  - **-DETERMINE WHAT WAS WRONG**
  - **-DRAW ATTENTION ON BEHAVIOR/PROCEDURES LEADING TO FAILURE**

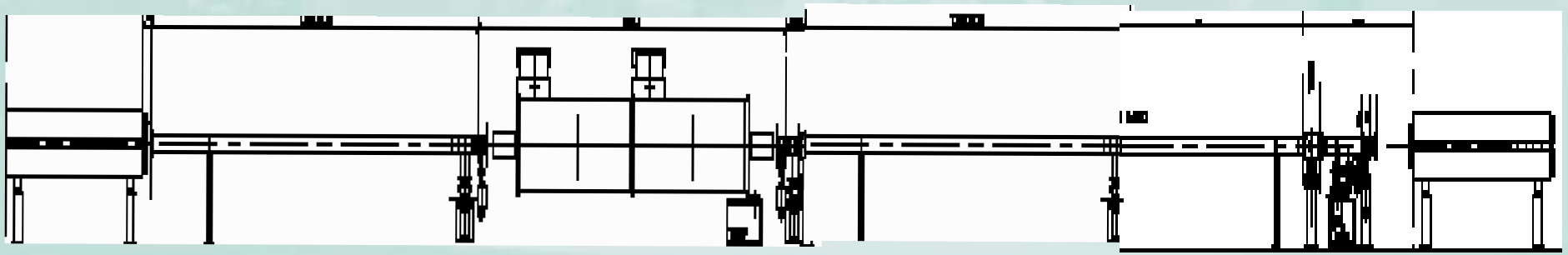
- **CONTENT**
  - **•OPERATION EXAMPLES**
  - **•THE LHC BELLOWS**
  - **•CORROSION**
- **THANKS**
  - ***• TO MY COLLEAGUES FOR THEIR HELP IN COMPLETING THAT PRESENTATION:***
  - ***• THE METALLURGICAL SECTION :S. SGOBBA, JP BACHER, G. ARNAU***
  - ***• C. HAUVILLER, M. JIMEMEZ, P.STRUBIN, K. ZAPFE***

OPERATION

- **GREAT VARIETY OF PROBLEMS**
  - **–FAULTY COMPONENTS**
  - **–PROCEDURES AND CONTROL**
- **EXAMPLES**
  - **–THE SPS SUPERCONDUCTING CAVITY**
  - **–THE LEP ENERGY UPGRADE**
  - **–MISCELLANEOUS**

OPERATION

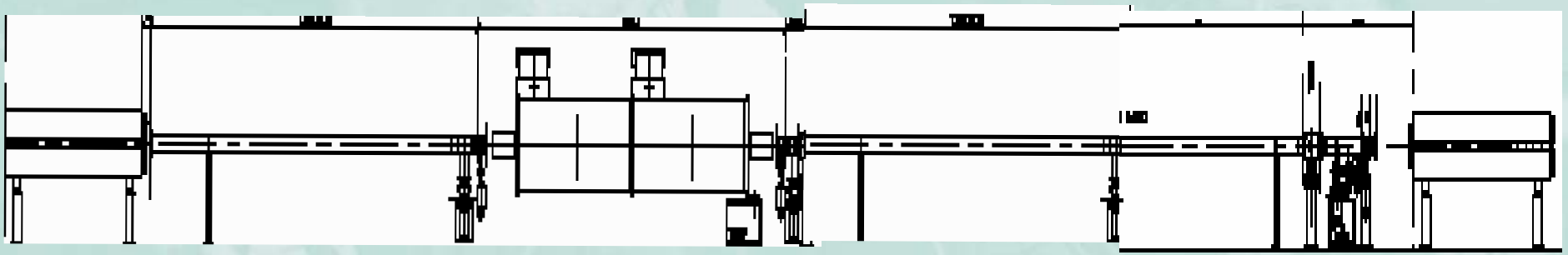
- **THE SPS SC. CAVITY:**
  - **–THE EVENTS**
    - *0 mn VACUUM ALARM: ION PUMPS SWITCHED OFF AND SECTOR VALVES CLOSED*
    - *12 mn LATER: CRYO ALARM: COMPRESSOR STOPPED*
    - *35 mn :ALARM LOW He IN CAVITY*
    - *39 mn : VACUUM ALARM SECTOR VALVES CLOSED AROUND CAVITY*



  - **CONSEQUENCES**
    - *AFTER COOL DOWN CAVITY HAS LOST RESONANCE!*
    - *RECOVERED AFTER COMPLETE WARM UP AND RECOOLING (CONDENSED GAS THICKNESS)*

OPERATION

- **THE SPS SC. CAVITY:**
  - **–ANALYSIS**
    - ***THE PROTON BEAM MADE A HOLE IN THE VACUUM CHAMBER***
    - ***SOME VALVES CLOSED, NOT THOSE BETWEEN THE HOLE AND THE CAVITY (NEEDS 3 BAD ION PUMP SIGNALS)***
    - ***FINALLY WHEN THE LIQUID HELIUM LEVEL WAS LOST THE SECTOR VALVES AFTER THE CAVITY CLOSED AND AVOIDED FURTHER PROPAGATION***



OPERATION

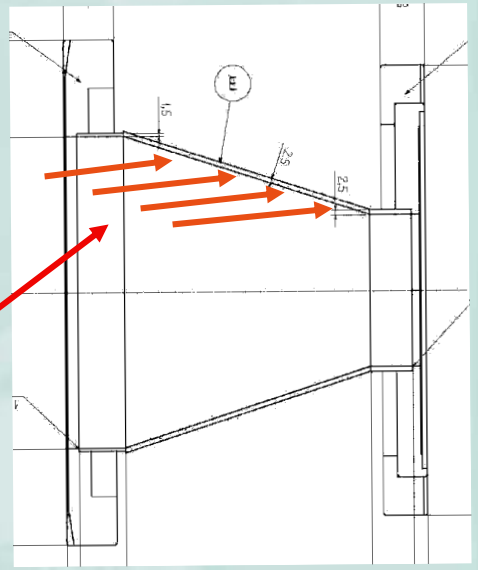
- **THE SPS SC. CAVITY:**
  - **–FAULTS AND REMEDIES**
    - ***FOR HISTORICAL REASONS INTERLOCKS WERE SET AT MAXIMUM (P.P-,80IES), A 3S DELAY WAS INTRODUCED TO ELIMINATE FALSE TRIGGERS***
    - ***AGING POWER SUPPLIES :***
      NO MORE ABLE TO DELIVER FULL CURRENT => => INTERLOCK LEVEL NO MORE REACHABLE
    - ***FAST VALVES WERE OPENED DESPITE BAD PRESSURE***

OPERATION

- **THE SPS SC. CAVITY:**
  - **–LESSONS**
    - ***INTERLOCK LEVELS DEPENDS ON THE OPERATION CONDITIONS***
    - ***THEY MUST BE PERIODICALLY REVIEWED AND KEPT TO A MINIMUM COMPATIBLE WITH SAFE OPERATION***
    - ***TOO MANY INTERLOCKS => BY-PASS***
    - ***A BY-PASSED INTERLOCK IS MORE DANGEROUS THAN NO INTERLOCK***

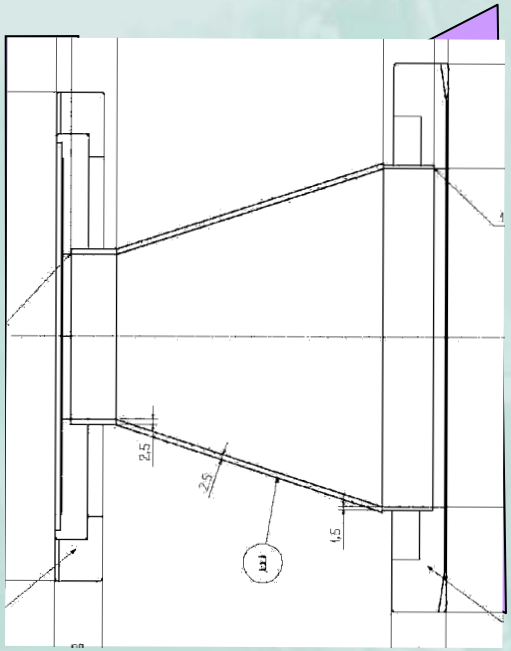
OPERATION

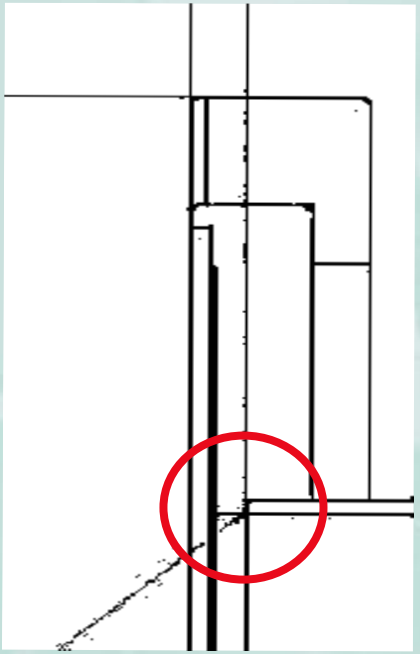
- **THE LEP ENERGY UPGRADE:**
  - **–GRADUAL ENERGY INCREASE**
    - ***FROM 45 GEV (1989) TO 100 GEV (1999) (i.e. 40->1000 W/m)***
    - ***SOME COMPONENTS DESIGNED FOR 45 GEV FORGOTTEN (UNCOOLED TRANSITIONS ELLIPTICAL-> CIRCULAR)***
    - ***INAPPROPRIATE FOR USE ABOVE 90 GEV (SYNCHROTRON LIGHT POWER)***
    - ***MANY FAILURES:***
      - –OVERHEATED CF GASKETS
      - –WELD FAILURES (REPEATED THERMAL CYCLES)

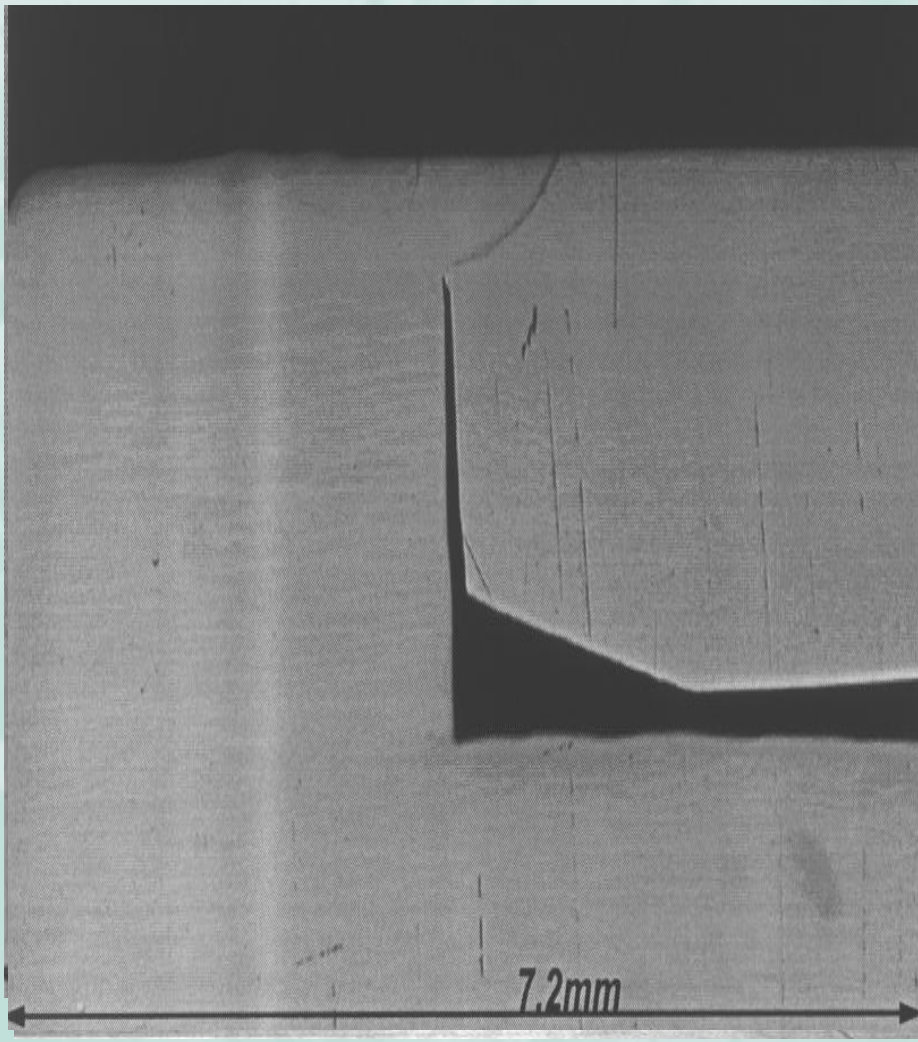


OPERATION

- **THE LEP ENERGY UPGRADE:**
  - **–WELD FAILURES:**
    - ***CLASSIC WELD***
      304 L TUBE / 316 LN FLANGE

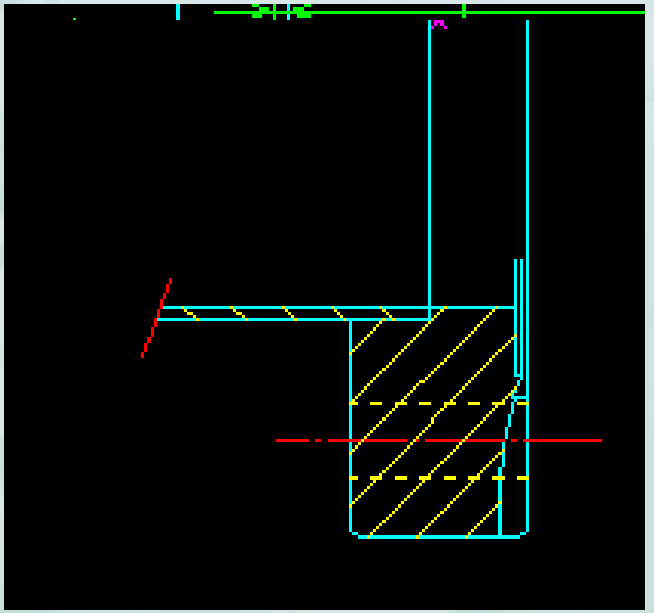


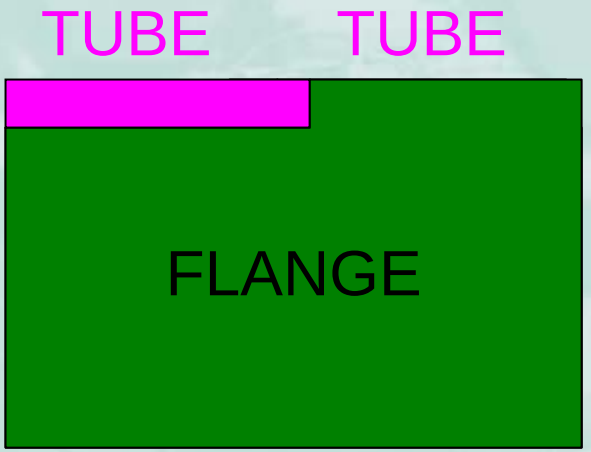




OPERATION

- **THE LEP ENERGY UPGRADE:**
  - **–ORIGIN**
    - *FORGOTTEN WEAK ELEMENT*
      +
    - *IMPROPER WELD PREPARATION: MASSIVE<->THIN PIECES*
    - *=>LACK OF PENETRATION FOR THE MASSIVE PART*
    - *WELDING LIPS PREFERABLE*





OPERATION

- **THE LEP ENERGY UPGRADE:**
  - **–LESSONS:**
    - ***PROVISIONAL IS DANGEROUS AND MUST BE TRACED***
    - ***WELL ORGANISED DATABASE OF COMPONENTS :***
      =>EASY TO FIND PIECES WITH SIMILAR GEOMETRIES
    - ***STANDARDISATION OF ESTABLISHED GOOD PRACTICE/RECEPIES***
      e.g. FOR WELD GEOMETRY

AND IMPOSE THEIR USE

OPERATION

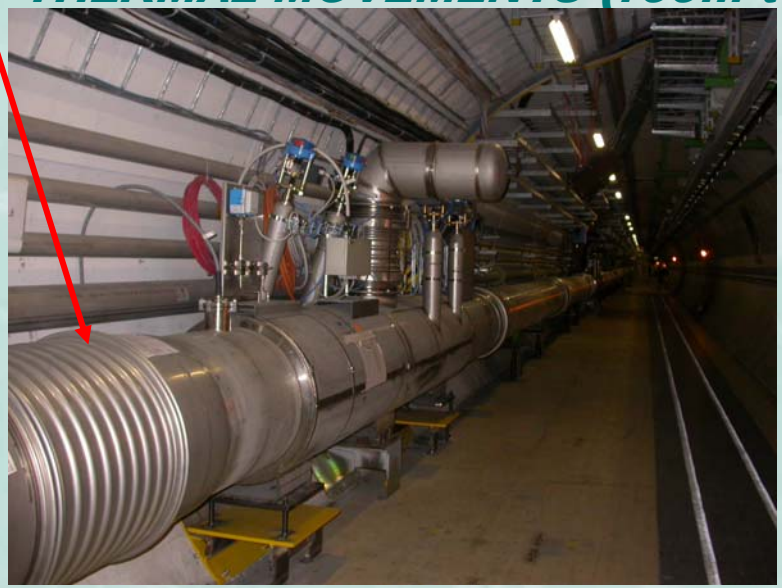
- **VENTING**
  - **–TYPICAL CASE**
    - *ROUTINE ACTIVITY*
    - *CONSIDERED AS SIMPLE (OBVIOUS!!)*
  - **–BUT…**
    - *COULD HELP YOU TO BECOME (VERY) POPULAR*
    - *NUMEROUS EXAMPLES IN ALL ACCELERATORS OF MISHAPS*
    - *COULD BECOME EXTREMELY EXPENSIVE : (DEMOUNTING/RINSING A SC MODULE)*
  - **–COMMON ERRORS**
    - *WRONG PLACE (SECTOR)*
    - *WRONG PRESSURE (COULD BE SPECTACULAR ON BELLOWS!)*
    - *WRONG FLUX FOR CRITICAL COMPONENTS (DUST FREE PLACES, LARGE ELECTRODES…)*

OPERATION

- **VENTING**
  - **–LESSONS**
    - ***PROPER LABELING OF VENTING VALVES***
    - ***COLLEAGUES CHECKING THE PRESSURE IN ADJACENT SECTORS DURING THE VENTING***
    - ***CAREFUL START OF GAS INJECTION : CHECK PRESSURE IN ADJACENT SECTORS***
    - ***TEAMS INFORMED OF ANOMALIES IN THE SECTORISATION (SECTOR VALVES BLOCKED OPEN)***
    - ***RELIABLE PRESSURE LIMITING SYSTEM (COULD BE AS SIMPLE AS A KF FLANGE WITHOUT COLLAR!)***

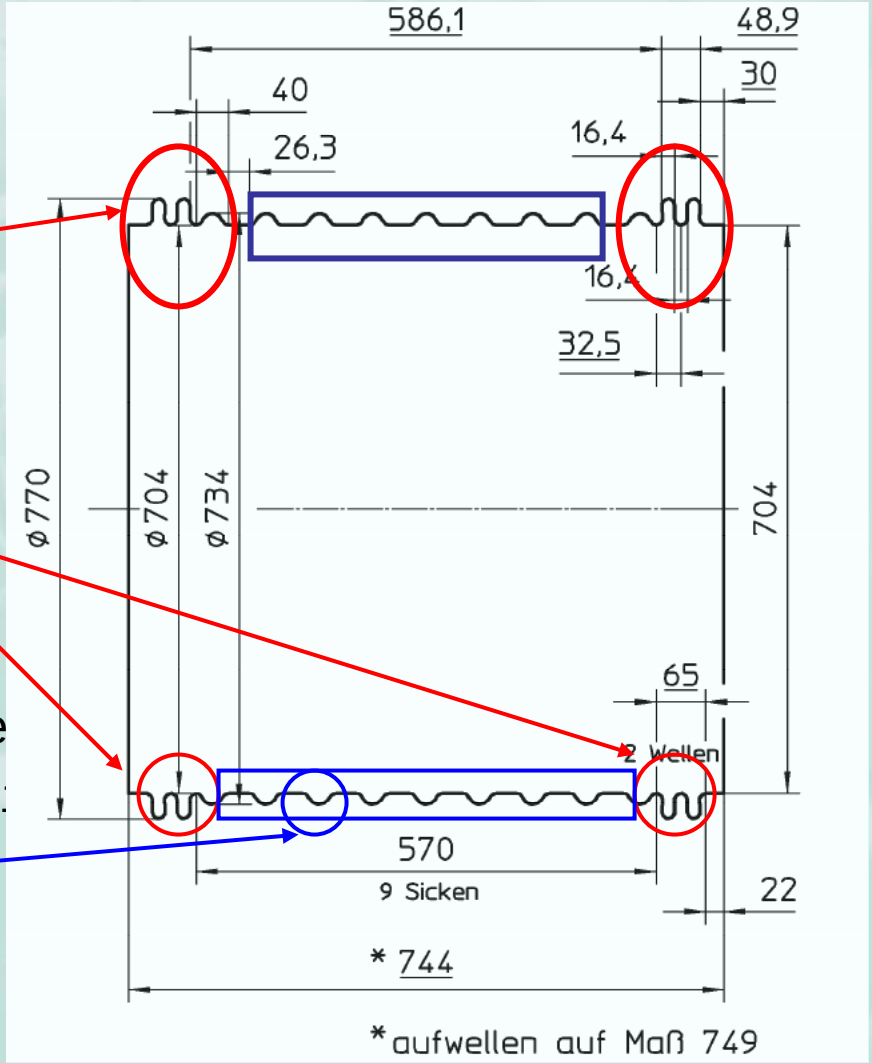
BELLOWS FAILURE

- **COURTESY C. HAUVILLER**
- **THE LHC CRYOGENIC LINE**
  - *LARGE COLLIDER OPERATING AT 1.9K*
  - *LIQUID HELIUM FEED*
  - **–FLEXIBLE ELEMENTS**
    - *ALIGNMENT*
    - *THERMAL MOVEMENTS (room temperature)*



BELLOWS FAILURE

- **BELLOWS DESIGN**
  - **Design:**
    - *Mainly for alignment:*
    - *=>"cardan design"*
    - *Limited temperature variation*
  - **Construction**
    - *4 large undulations (flexibility)*
    - *Rigid spacer*
      - For economical reasons:
        spacer same material/thickne
      - ⇒Undulations needed for rigid
      - Nominal height 15mm



BELLOWS FAILURE

- **STABILITY CALCULATIONS**
  - **–Calculated according to ASME code**

Straight Pipe Under External Pressure

Center connector

Moment of inertia:

$I_{connector}$	=	14562	mm^4	
L	=	570	mm	
t_{pipe}	=	6.7	mm	(equivalent pipe thickness)
pd	=	1	bar	
T	=	20	C	(68 F)
Do	=	734	mm	
t	=	6.7	mm	
L / Do	=	0.777	-	
Do / t	=	108.86	-	

Factors :

A	=	0.0132	-	Fig. G; ASME II, Part D, Subpart 3
B	=	15000	-	Fig. HA-1; ASME II, Part D, Subpart 3 (ALLOY 316)

$$p_a = \frac{4 \cdot B}{3 \cdot \left(\frac{D_o}{t}\right)} = 12.67 \text{ bar}$$

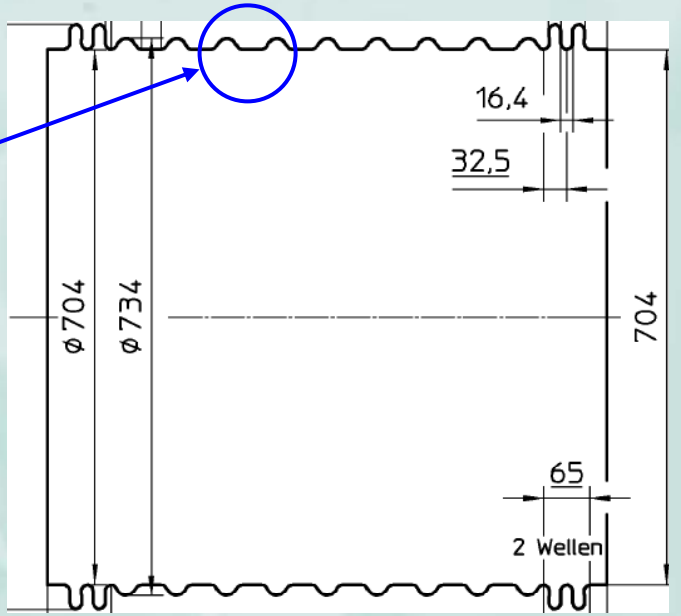
pd = 1 bar <

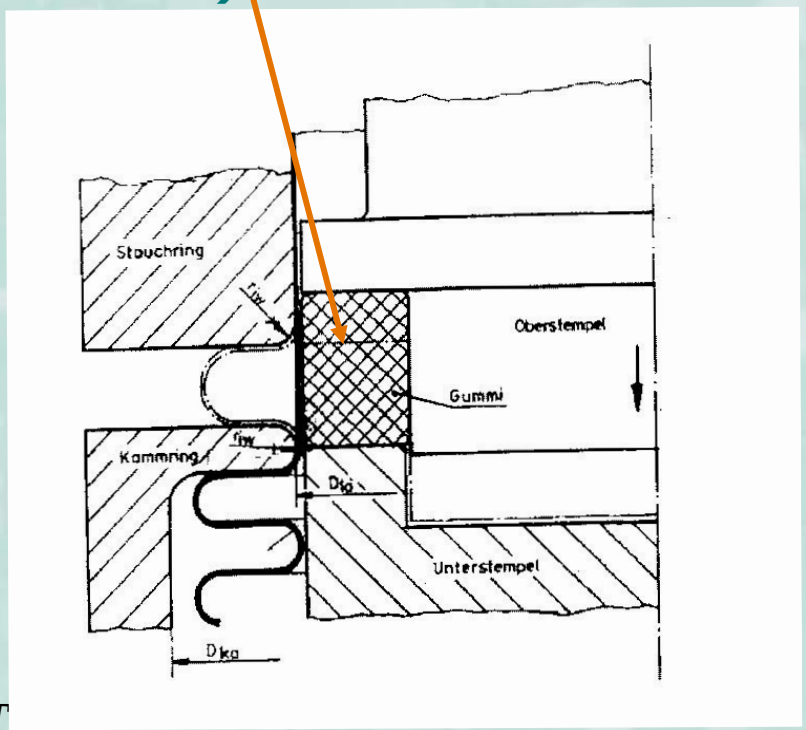
BELLOWS FAILURE

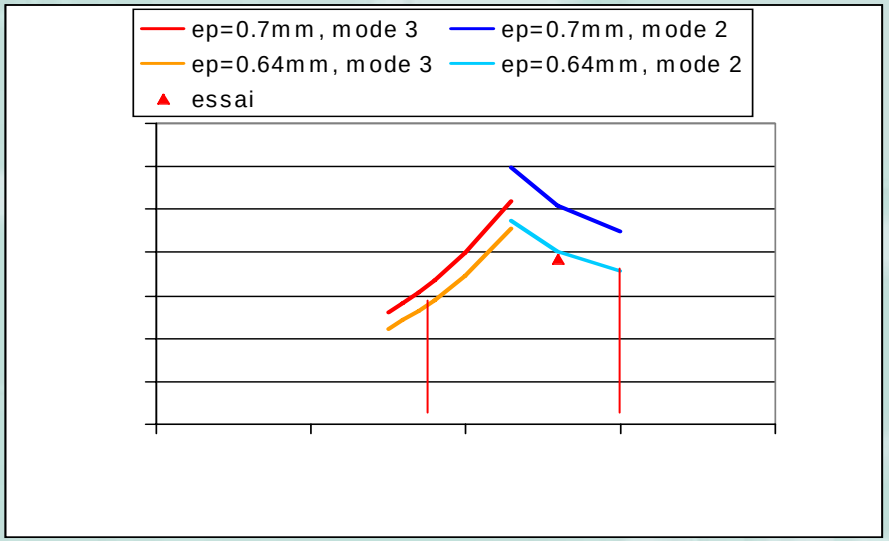
- **RESULTS**
  - **–Initial installation without problem**
  - **–Collapses after impacts**
  - **–But later without external intervention**

BELLOWS FAILURE

- **ANALYSIS**
  - **–CONVOLUTIONS TOO SMALL :**
    - ***NOMINAL 15mm***
    - ***MEASURED 8 mm***
    - ***DRIFT DURING THE PRODUCTION (TOOLING)***



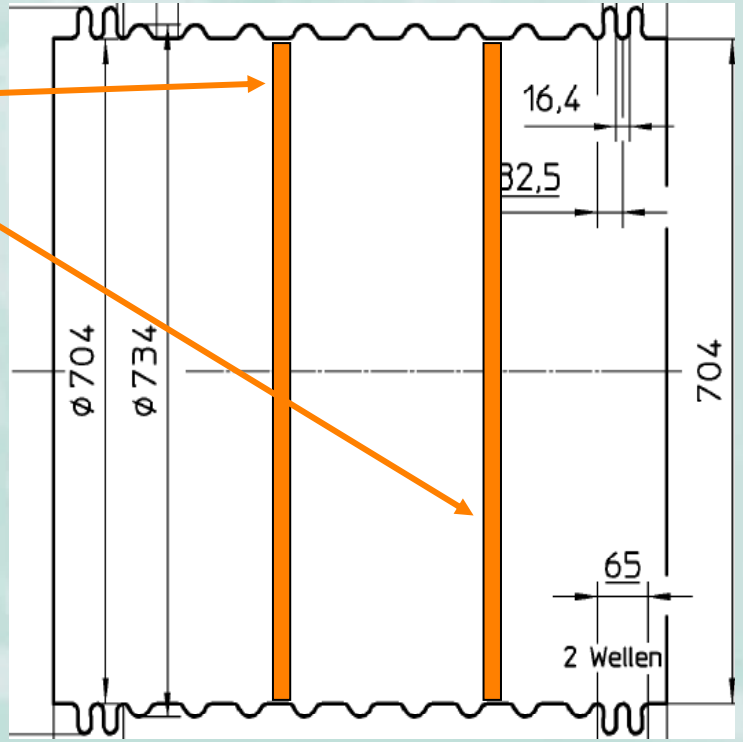




BELLOWS FAILURE

- **CURE**
  - **–2 REINFORCEMENT RINGS**

- **ORIGIN**
  - ***INAPPROPRIATE CODE FOR CALCULATIONS (thin walls)***
  - ***UNMONITORED DRIFT DURING FABRICATION***
  - ***Note: PRODUCED BY A SUB-CONCTRACTOR OF THE MAIN CONTRACTOR***



BELLOWS FAILURE

- **LESSONS**
  - **–BYING “TURN KEY” SYSTEM IS NOT AS SIMPLE AS FORESEEN**
  - **–HENCE A CAREFUL FOLLOW UP OF PRODUCTION IS MANDATORY EVEN AT THE STAGE OF COMPONENTS**
  - **–THE QUALITY PLAN OF THE CONTRACTOR MUST BE CHECKED**
  - **–COMMON INSPECTIONS MUST BE MADE AT THE SUBCONTRACTORS**

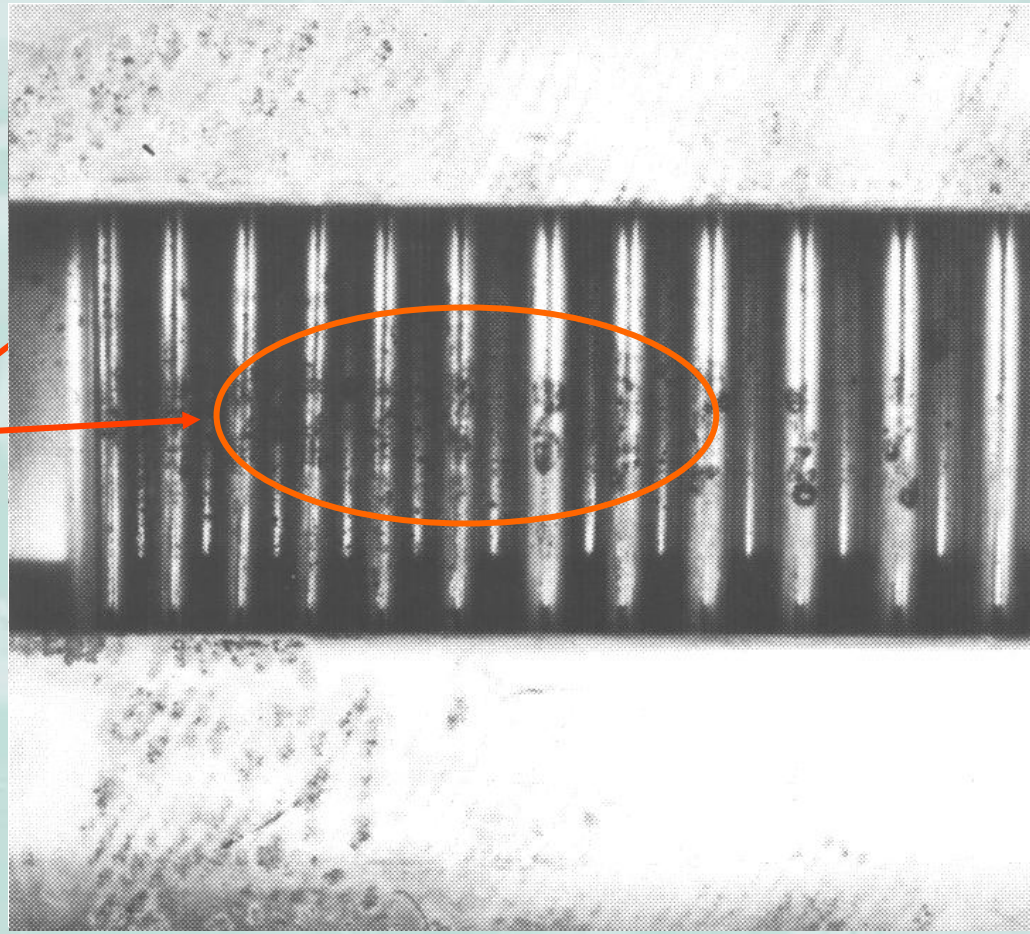
CORROSION

- **A LONG STORY IN ACCELERATORS**
  - **–MILD MEDIUM**
    - *PROTECTED AGAINST AGGRESSIVE MEDIA (limited humidity)*
    - *NO AGGRESSIVE AGENTS (O_3 Nox. EXCEPTED) ALLOWED*
  - **–RESISTANT MATERIALS :**
    - *STAINLESS STEELS*
    - *ALUMINUM*
    - *COPPER*
- **BUT….**
  - **–NUMEROUS EXAMPLES IN ALL MACHINES**
  - **–CAUSES KNOWN SINCE LONG**
  - **–ALWAYS REAPPEARING**

……..SOMETIMES FOR IDENTICAL REASONS !!

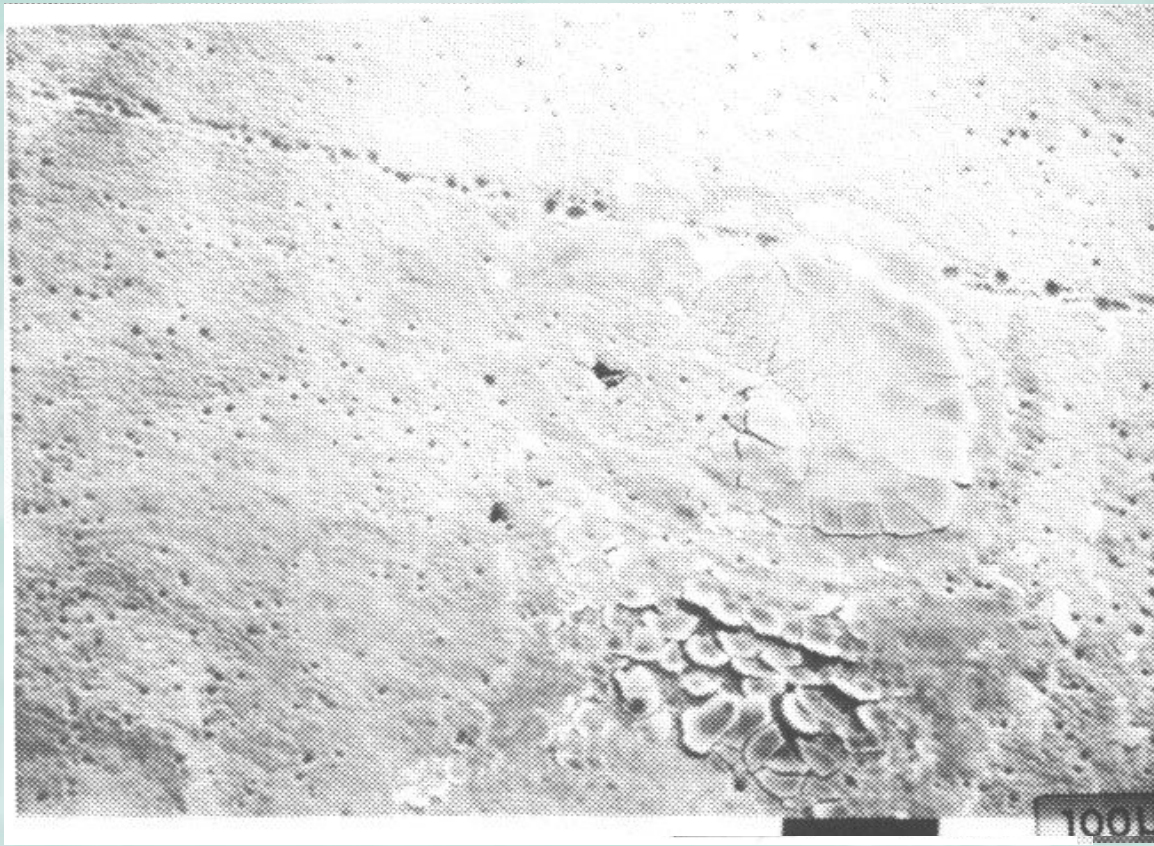
CORROSION

- **FIRST BELLOW STORY:**
  ISR SUMMER 1980
  - *LEAK ON A QUAD CHAMBER (BELLOW) INSTALLED FOR 1 YEAR*
  - *MATERIAL ST.STEEL 316 L*
  - *HEAVY OXIDATION VISIBLE WHERE THE BELLOWS WAS ACCESSIBLE*



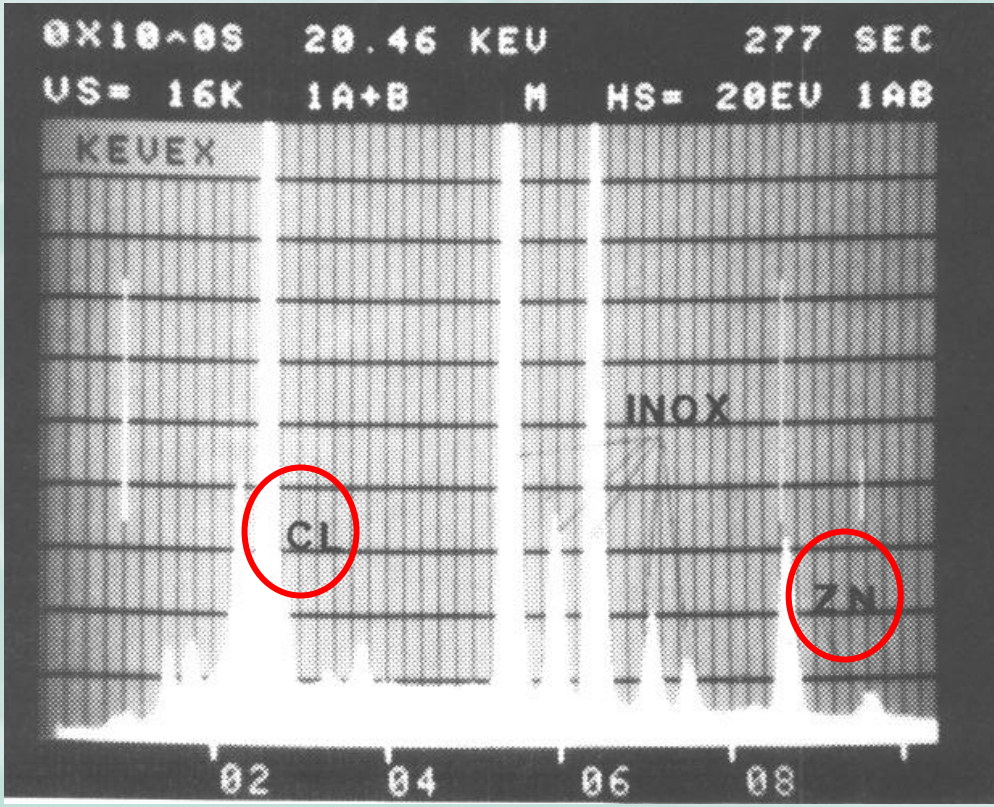
CORROSION

- **FIRST BELLOW STORY: ISR (COURTESY J.P. BACHER)**
  - ***LEAK FROM OUTSIDE***
  - ***CLOSER….***
  - ***AND FROM INSIDE***



CORROSION

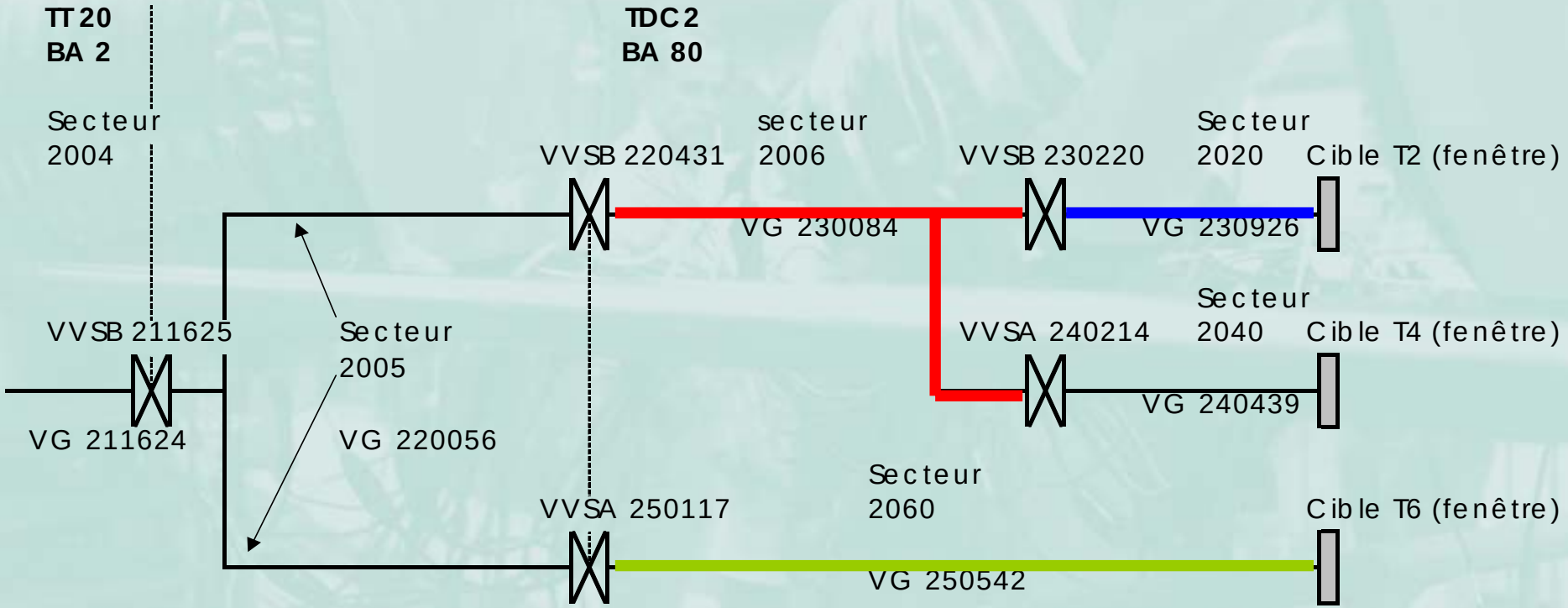
- **ISR BELLOW: ORIGIN OF FAILURE**
  - *CULPRIT HAS LEFT TRACES*
  - *CORROSION BY BRAZING FLUX (*$ZnCl_2$)*
  - *ST.STEEL EXTREMELY SENSITIVE TO Cl PITTING*



–BRAZING ACTIVITIES WITHOUT PROTECTION (and care) ON ADJACENT MAGNET

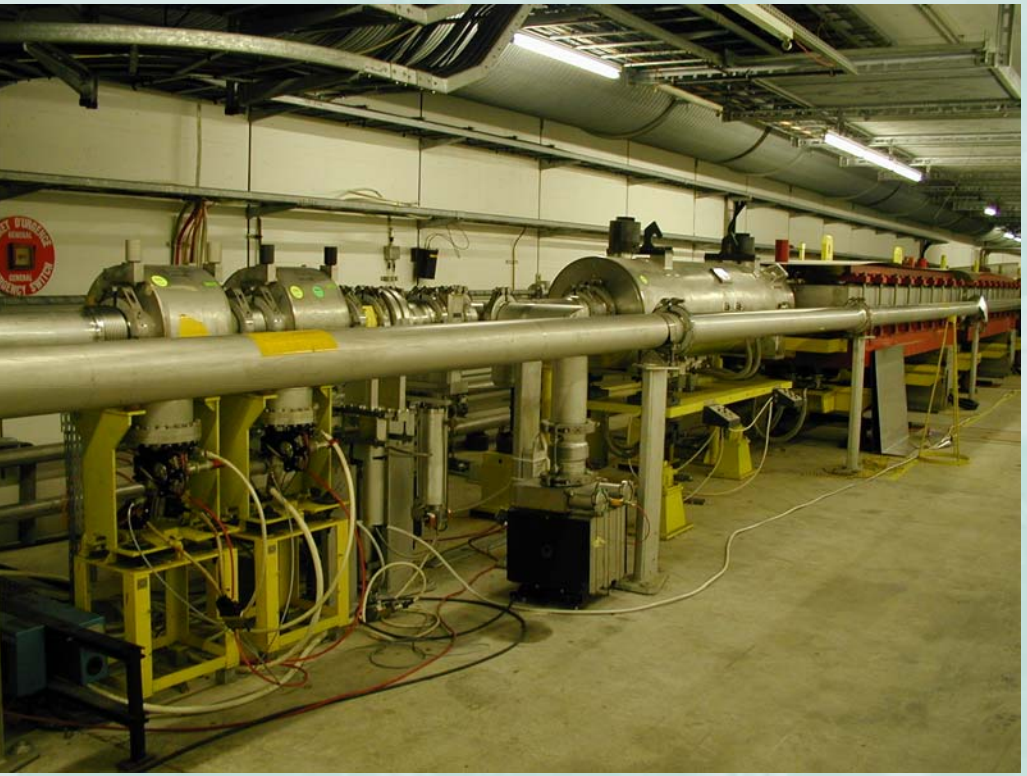
CORROSION

- **THE SPS HORROR SHOW (COURTESY M. JIMENEZ)**
  - **–400 GeV SYNCHROTRON (LHC INJECTOR)**
    - ***FIXED TARGET PHYSICS***
    - ***HIGH RADIATION AREA (5x10^5 Gray/year)***
    - ***ALL ST. STEEL CONSTRUCTION (304 L)***



CORROSION

- **THE SPS HORROR SHOW**
  - **–SEEN FROM "RADIATION SAFE" DISTANCE:**
    - ***NORMAL***
- **BUT…..**



CORROSION

- **THE SPS HORROR SHOW**
  - **–CLOSER**

CORROSION

THE SPS HORROR SHOW

- OTHER EXAMPLES

-

CORROSION

- **THE SPS HORROR SHOW**
  - **–VERY COSTLY:**
    - ***TIME LOST FOR EXPERIMENTS***
    - ***MORE THAN 25 INTERVENTIONS OF THE VACUUM PIQUET IN 6 WEEKS (>4/WEEK!)***
    - ***HIGH RADIATION ZONE ⇨ 27 PEOPLES INVOLVED SHARING 21 mSv***
    - ***REPLACEMENT OF A COMPLETE SECTOR (30 m)***
      - *»13 CHAMBERS AND 14 BELLOWS MANUFACTURED AND EXCHANGED IN ONLY 5 DAYS*
    - ***CHAMBERS PROTECTED BY ALUMINUM FOIL***

CORROSION

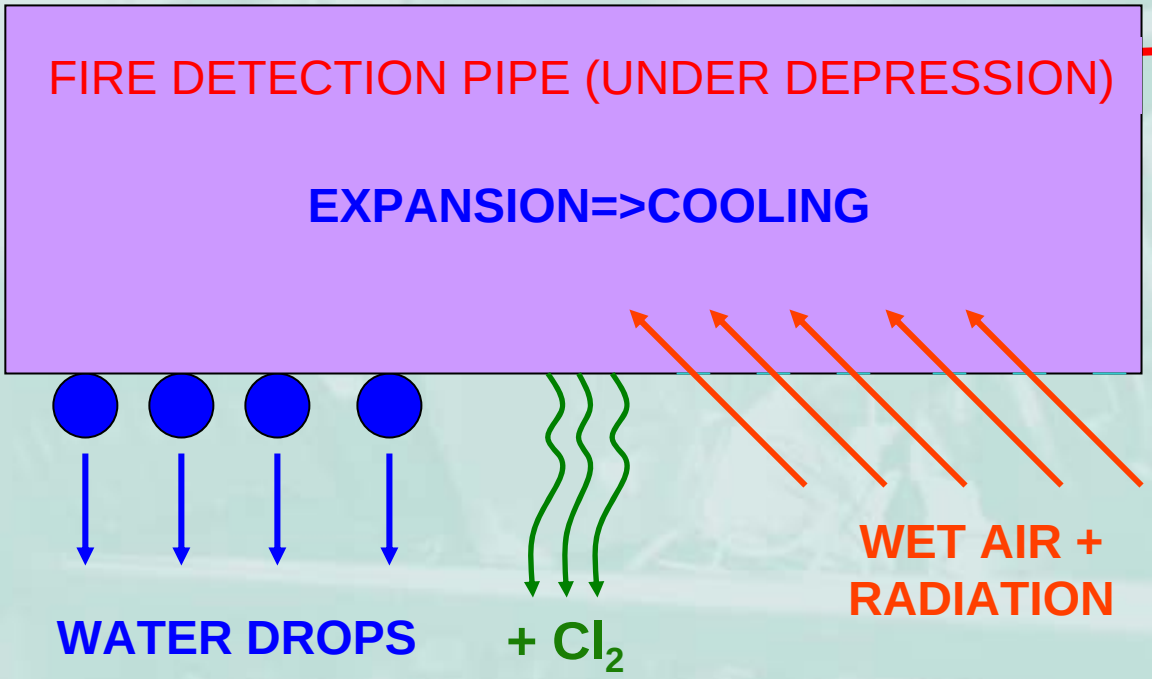
- **THE SPS HORROR SHOW: ORIGIN**

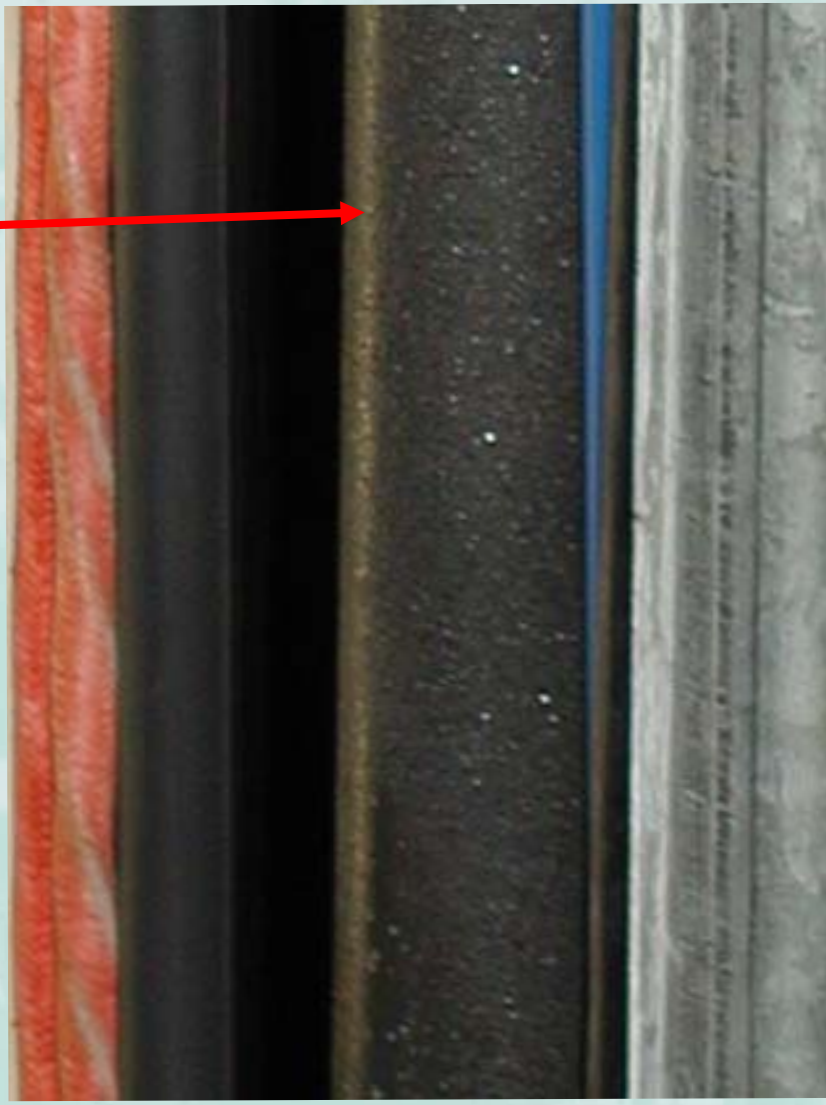
–MOST DAMAGES ON TOP OF COMPONENTS: CABLE TRAY

–NOTE DISCOLORATION!!

CORROSION

- **THE SPS HORROR SHOW: ORIGIN**

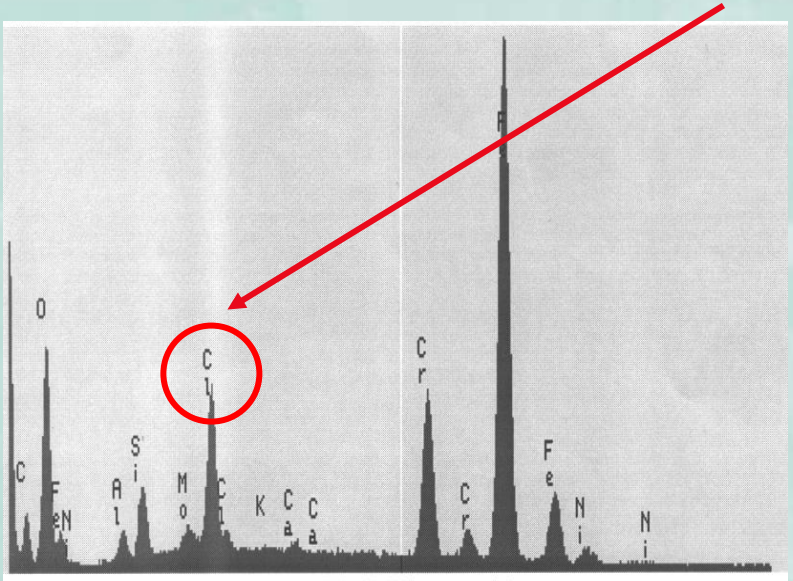


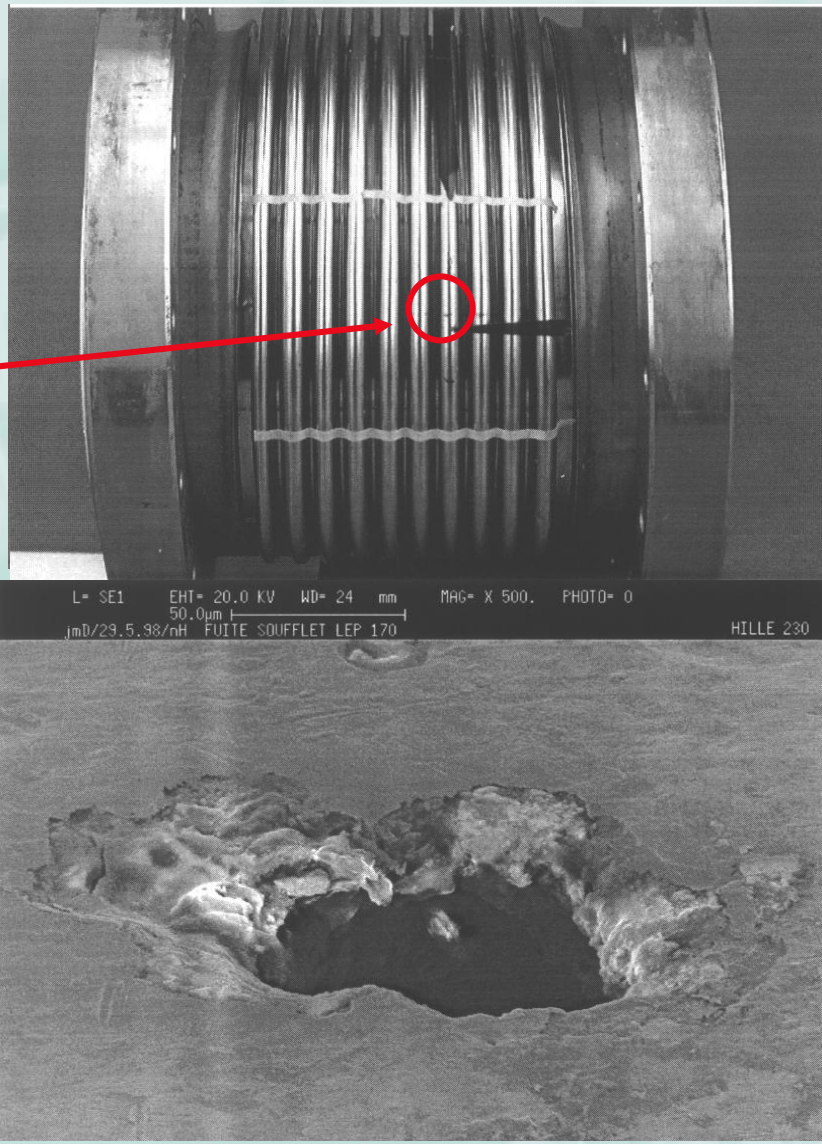


–THE FIRE DETECTION PIPE WAS MADE OF PVC!!!

CORROSION

- **THE LEP BELLOWS:**
  - ***A bellows in LEP injection region (high radiation area)***
  - ***Leak position:***
  - ***Presence of chlorine***

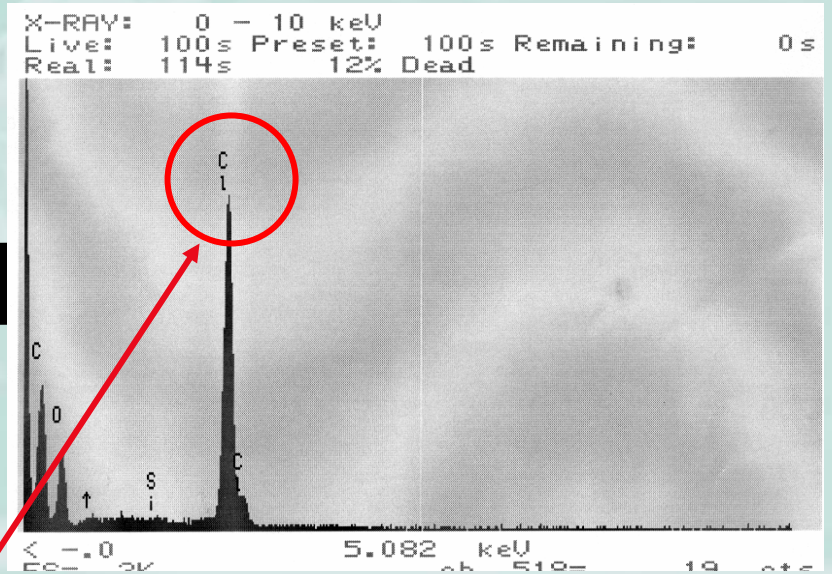




CORROSION

• THE LEP BELLOWS: ORIGIN

- *SIGNAL NEEDED FOR THE INJECTION TIMING*
- *TRIGGER GIVEN BY A PHOTOMULTIPLIER*
- *TRANSPARENCY <=> MORE SENSITIVITY*
- *=> BELLOWS IDEAL*
- *PHOTOMULTIPLIER AS CLOSE AS POSSIBLE TO THE BEAM*
- *=> TOUCHING THE BELLOW*



–BUT

- *THE ADHESIVE BLACK TAPE AROUND THE PHOTOMUTILPIER CONTAINED CHLORINE (PVC BASED)!*

CORROSION

- **LESSONS**

FAILURES AND MISCONCEPTIONS

- **CONCLUSIONS**

  –DESCRIBED FAILURES ORIGINATE FROM WELL KNOWN MISCONCEPTIONS

  –EVERY FAILURE MUST BE INVESTIGATED, EXPLAINED AND RECORDED

  –GOOD PRACTICE DIFFICULT TO INTRODUCE BEFORE FAILURE

  –HABITS (EVEN BAD) TEND TO PERPETUATE:

  - ***"ONE HAS ALWAYS DONE LIKE THIS"***

  –"TURN KEY SYSTEMS" ARE VERY DIFFICULT TO CONTROL

FAILURES AND MISCONCEPTIONS

CONCLUSIONS

–DEVELOP INTERNAL STANDARDS FOR ENGINEERING AND CRITICAL PRODUCTION/OPERATION STEPS (e.g. WELDING, CLEANING, VENTING, BAKING…)

…AND HAVE THEM APPLIED!!

–PERIODIC REVIEW OF LAYOUTS, PROCEDURES AND INTERLOCKS TO ELIMINATE OBSOLETE (DANGEROUS) SITUATION

- ***A GOOD WALK IN THE ACCELERATOR IS HEALTHY FOR THE SUPERVISOR AND.. THE ACCELERATOR***


THANK YOU FOR YOUR ATTENTION